SEASONAL MOVEMENTS OF THE WINTER, FLOUNDER, PSEUDOPLEURONECTES AMERICANUS (WALBAUM) IN TWO CONTRASTING INSHORE LOCATIONS IN NEWFOUNDLAND

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SEASONAL MOVEMENTS OF THE WINTER FLOUNDER, *PSEUDOPLEURONECTES AMERICANUS* (WALBAUM), IN TWO CONTRASTING INSHORE LOCATIONS IN NEWFOUNDLAND

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ABSTRACT

Seasonal movements of the winter flounder, *Pseudopleuronectes americanus* (Walbaum) 1792, were examined in a protected inlet and an exposed cove in Conception Bay, Newfoundland, from February, 1973, to March, 1974. Movements in the two locations were compared with each other and with two hypotheses of winter flounder movement in the literature. Seasonal movements of the winter flounder from Newfoundland to Maryland are reviewed. A general scheme of seasonal movements of the winter flounder throughout its range is suggested.

In the present study movements were inferred from changes in flounder abundance. Abundance on a given date was determined by counting fish on a fixed area of bottom using SCUBA. Environmental and physiological factors were examined in an attempt to determine the causes of movement.

Winter flounder movements in the protected inlet and exposed cove were somewhat similar in all seasons except winter. During the winter of 1973 flounders were present in shallow water in the protected inlet until drifting pack ice entered the region. The following winter, fish were scarce in the protected inlet. This scarcity coincided with the heavy turbulence of that winter. Flounders left the shallows of the exposed cove in both winters, probably because of turbulence and perhaps drifting ice. In June many winter flounders moved into the shallows of the protected inlet and a few entered the exposed cove, where they spawned. Flounders left both regions in July or August in

what may have been feeding migrations. In August or September flounders returned to the shallows of both locations. This immigration coincided with peak water temperatures and the initiation of ripening of the gonads. In the fall they left the shore zone of both sites during severe storms and returned to the shallows as the turbulence subsided.

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INTRODUCTION

The winter flounder, *Pseudopleuronectes americanus* (Walbaum) 1792, ranges from Labrador to Georgia and has been reported from several regions around Newfoundland (Bigelow and Schroeder, 1953; Leim and Scott, 1966). Inshore-offshore seasonal movements of the winter flounder have been described from Newfoundland to Maryland (Bigelow and Schroeder, 1953; Bigelow and Welsh, 1925; Dickie and McCracken, 1955; Kennedy, 1964; Kennedy and Steele, 1971; Levings, 1973; Lobell, 1939; Lux and Nichy, 1971; McCracken, 1963; Neville and Perlmutter, 1940; Pearcy, 1962; Richards, 1963; Saila, 1961; Schwartz, 1964; Smith and Cole, 1970; Tyler, 1971a; Warfel and Merriman, 1944). It is apparent that these movements are not the same in all regions in which they have been examined. It has been suggested that flounder movements are controlled by such factors as water temperature (Lobell, 1939; McCracken, 1963), food availability (Kennedy and Steele, 1971), and the reproductive condition of the gonads (Kennedy, 1964; Lobell, 1939; Pearcy, 1962). McCracken (1963) presented a hypothesis to describe the seasonal movements of the winter flounder throughout its range. Kennedy (1964) reported that flounder movements in Long Pond, Newfoundland, did not fit McCracken's hypothesis, and another hypothesis was proposed by Kennedy and Steele (1972). The present study was undertaken to provide additional information on flounder movements and their causes in northern regions to compare to the above hypotheses. Two locations in the shore zone of Conception Bay, Newfoundland, were chosen as study sites. One site was a narrow, protected inlet and the other was a shallow, exposed cove. Changes in flounder abundance in separate stations within each study site were recorded over a period of approximately thirteen months to provide information on their movements. These movements were then compared with environmental and physiological factors in an attempt to determine why the movements occurred. A tentative scheme is suggested to describe seasonal movements of winter flounder throughout their range, and the causes of these movements.

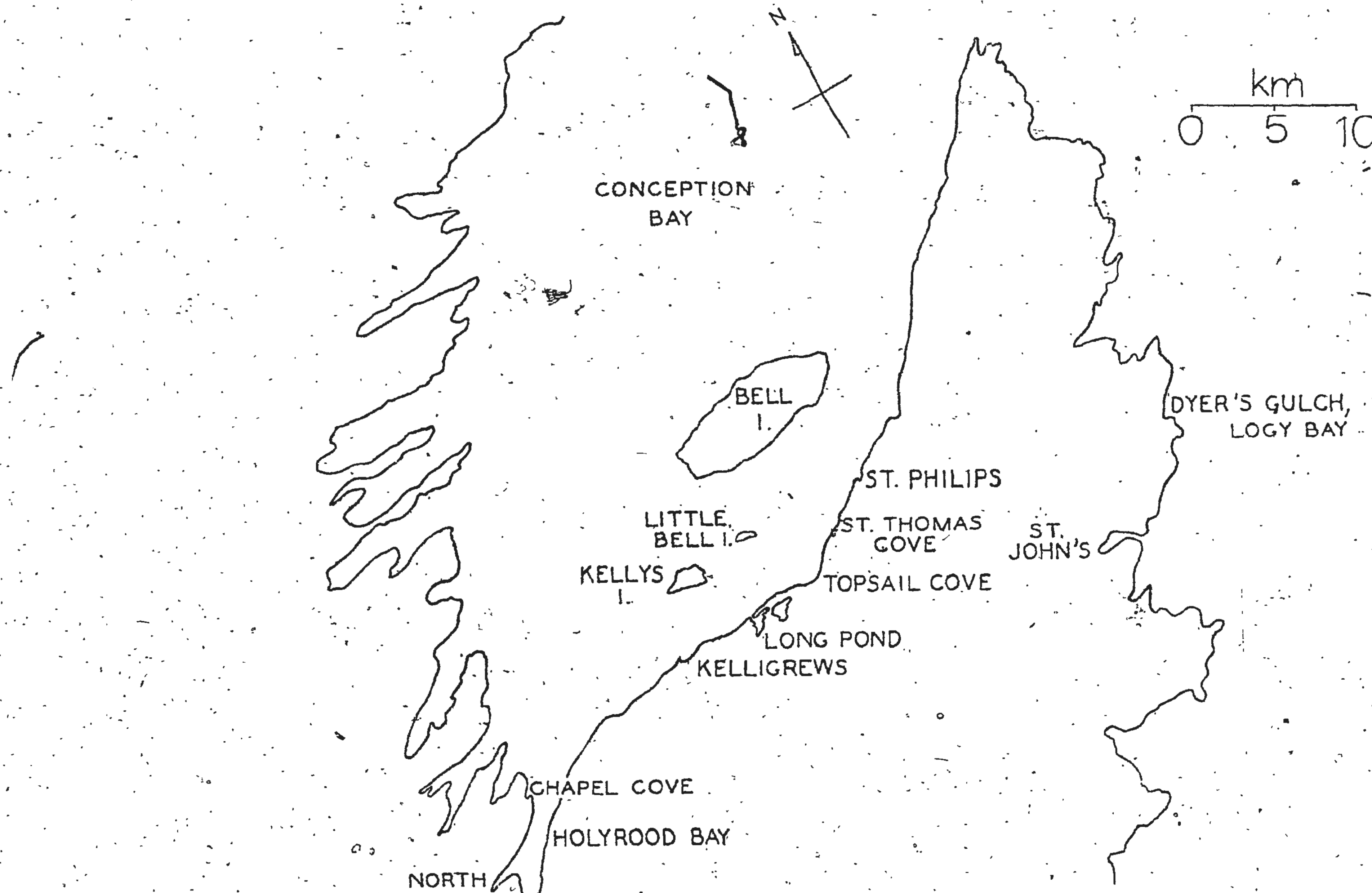
I. DESCRIPTION OF THE STUDY SITES

The two sites chosen for the present study are located in Conception Bay on the Avalon Peninsula of eastern Newfoundland (Figure 1). Conception Bay is approximately 55 km long with a maximum width of 25 km and a maximum depth of 295 m. Holyrood Bay, at the very head of Conception Bay, is divided into a North and a South Arm. The North Arm was chosen as one study site (Figure 2). It is a protected inlet with a stream running into its head. It is approximately 1.5 km long and it narrows from approximately 750 m in width to 100 m. The head of North Arm averages 1-2 m deep, increasing gradually to about 18 m at its mouth. Mussel beds and gravel comprise the bottom at the very head, at depths of 2 m or less. This quickly changes to very soft, sandy mud, which covers the rest of the bottom except for scattered patches of rock and gravel. The steep bank is rocky all the way around.

The second study site, Broad Cove at St. Philips (Figure 3), is located about one-half of the distance along the southern shore of Conception Bay from North Arm (Figure 1). Broad Cove is a small, exposed cove facing directly into Conception Bay; it is somewhat protected by Bell Island. A small stream flows into the southwestern corner of the cove. This widens to form a small harbor, and a government wharf projecting into the cove protects the entrance of the harbor. The cove measures approximately 500 m across the mouth and approximately 250 m from mouth to shore. At the mouth of the cove the average depth is 12-13 m. The bottom within the cove is principally bedrock and boulder, as is the surrounding shoreline. Just off the right headland of the cove, facing seaward, the bottom quickly changes from rock and cobble to sand, remains sandy for roughly 300 m offshore, and then becomes rocky again.

FIGURE 1

Conception Bay.



N
km
0 5 10
CONCEPTION BAY
BELL I.
LITTLE BELL I.
KELLYS I.
ST. PHILIPS
ST. THOMAS COVE
TOPSAIL COVE
LONG POND
KELLIGREWS
CHAPEL COVE
HOLYROOD BAY
NORTH ARM
ST. JOHN'S
DYER'S GULCH, LOGY BAY

6

FIGURE 2

North Arm.

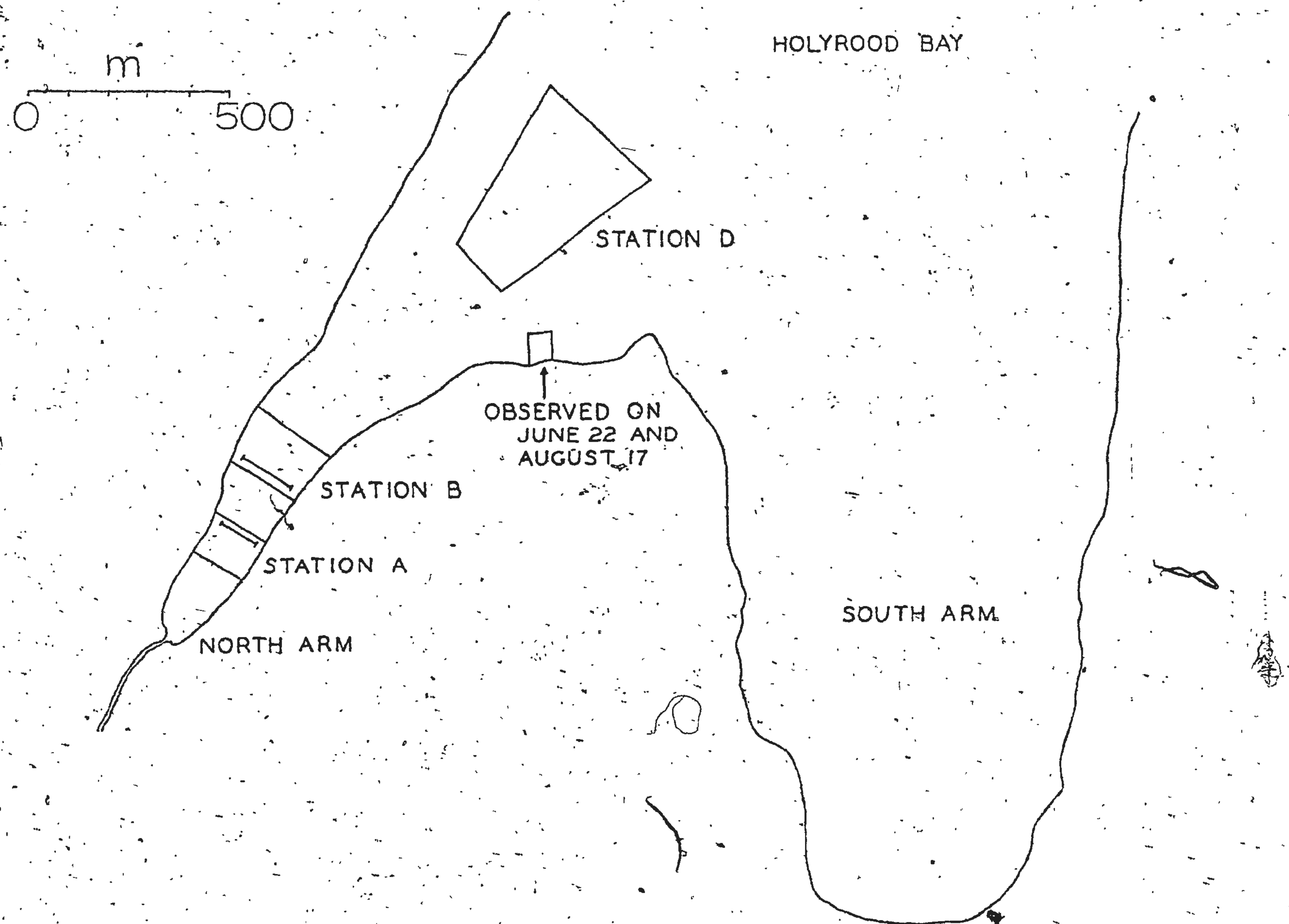
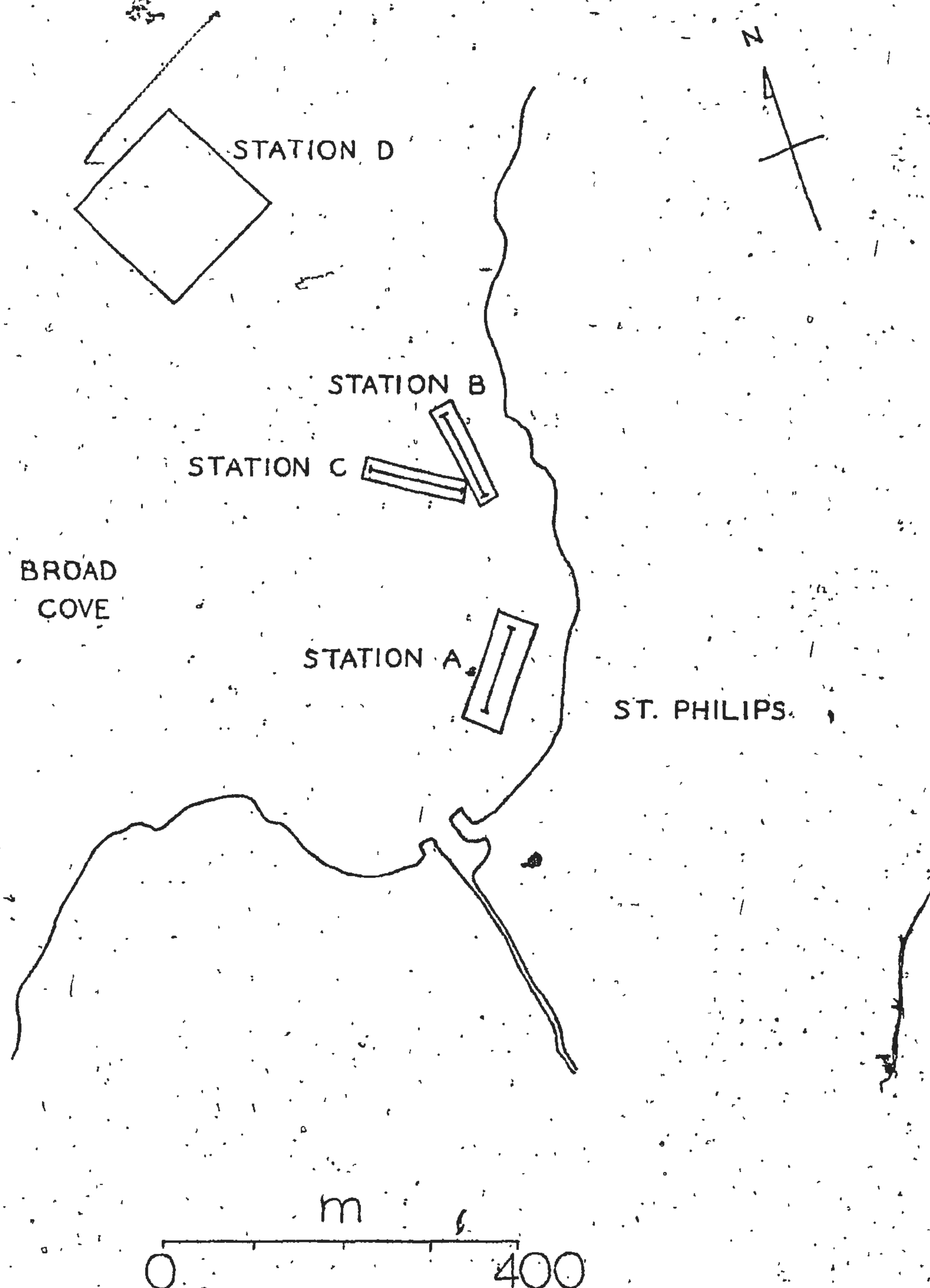

m
0
500
HOLYROOD BAY
STATION D
OBSERVED ON
JUNE 22 AND
AUGUST 17
STATION B
STATION A
NORTH ARM
SOUTH ARM

FIGURE 3

St. Philips.


N
STATION D
STATION B
STATION C
BROAD
COVE
STATION A
ST. PHILIPS
m
0
400

II. METHODS

A. Seasonal Movements

North Arm and St. Philips were chosen as study sites because they are close together geographically but have different substrata and degrees of exposure. Specific regions in North Arm and St. Philips were designated as stations (Figures 2 and 3). Table 1 gives a brief description of each station. Seasonal movements of winter flounders in North Arm and St. Philips were noted by observing changes in their abundance in the different stations from February, 1973 to March, 1974. Differences in movement within the two study sites could then be compared. All stations were established in January, 1973 except St. Philips Station C, which was established on June 29 to give a better picture of flounder distribution and movement at St. Philips.

The abundance of winter flounders within each station was determined by counting those within a fixed area of bottom using SCUBA. From February to April, 1973, counts were made using a portable quadrat in Stations A and B of both study sites. In late April a permanent transect was established at each of these stations for counting. In St. Philips Station C a permanent transect was used throughout. In the deeper Stations D of North Arm and St. Philips all flounders observed throughout each dive were simply counted. The exact dates on which these methods were used are given in Appendices L and M.

TABLE 1

Characteristics of the stations within each study site

	North Arm			St. Philips			
	Station A	Station B	Station D	Station A	Station B	Station C	Station D
depth range (meters)	3 - 6	7.5 - 12.5	15 - 18	3 - 7.5	7.5 - 10.5	10.5 - 14	16 - 29
bottom type	mud	mud, one patch of rocks	mud, sparse cobble	boulder	sand and cobble	sand	sand, sparse cobble, and rocks

1. Portable Quadrat Technique

The portable quadrat consisted of an innertube, a lead anchor, and an anchor line which had a permanent loop fixed approximately 1.5 m above the anchor. This apparatus was towed out into a given station, the anchor was lowered, and the anchor line was fixed to the innertube. Attached to the loop in the anchor line by a clip was a 6-m length of rope. This rope was stretched parallel to the bottom. By swimming in a circle around the anchor and counting all flounders lying beneath the rope, the abundance of flounders in a given area could be determined. Pulling on the rope produced a bend in the anchor line, and the distance between the anchor and the perpendicular to the clip was about 1 m (Figure 4). This gave a counting area of approximately 150 square meters, which is defined as one count using the portable quadrat technique. Usually two counts were made on each dive.

Because winter flounders often bury themselves almost completely, especially in winter, wooden poles with thin plastic tips were used to probe the bottom while swimming around the anchor. This method proved advantageous in North Arm because the muddy bottom could be searched without stirring up obscuring clouds of silt. In the sandy regions of St. Philips it was found that partially and completely buried flounders could be observed without using the poles, and their use there was discontinued.

There was a disadvantage to the portable quadrat technique. If the distribution of winter flounders within a station was not uniform, then one or two counts would not give an accurate representation of abundance in that station. This did not occur at St. Philips since flounders were absent there while the portable quadrat was in use.

FIGURE 4

The portable quadrat technique.

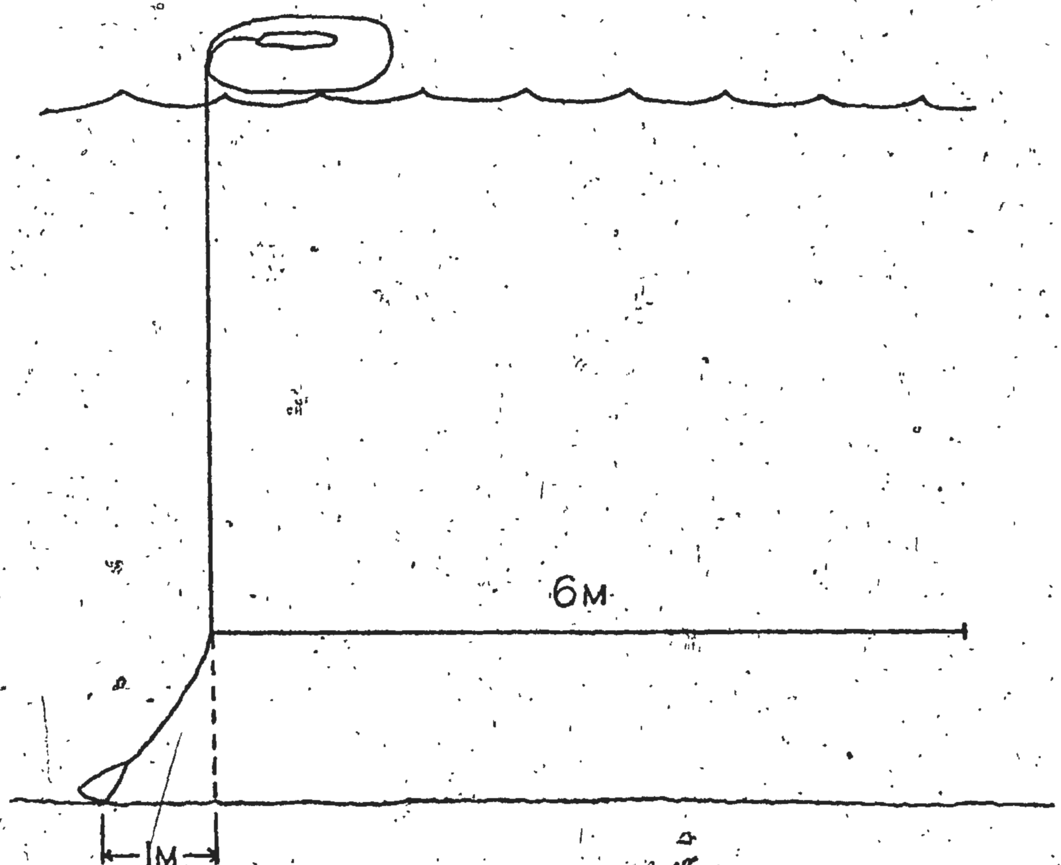
$R_1 = (6+1)\,M$

$R_2 = 1\,M$

$\text{AREA} = \pi R_1^2 - \pi R_2^2$

$= (3.14 \times (6+1M)^2) - (3.14 \times (1M)^2)$

$= 150.7\,M^2$



It is unknown if the distribution in North Arm Station B was not uniform during this period. But such a distribution occurred in North Arm Station A in mid-April, apparently for the first time since the study began.

2. Transect Technique

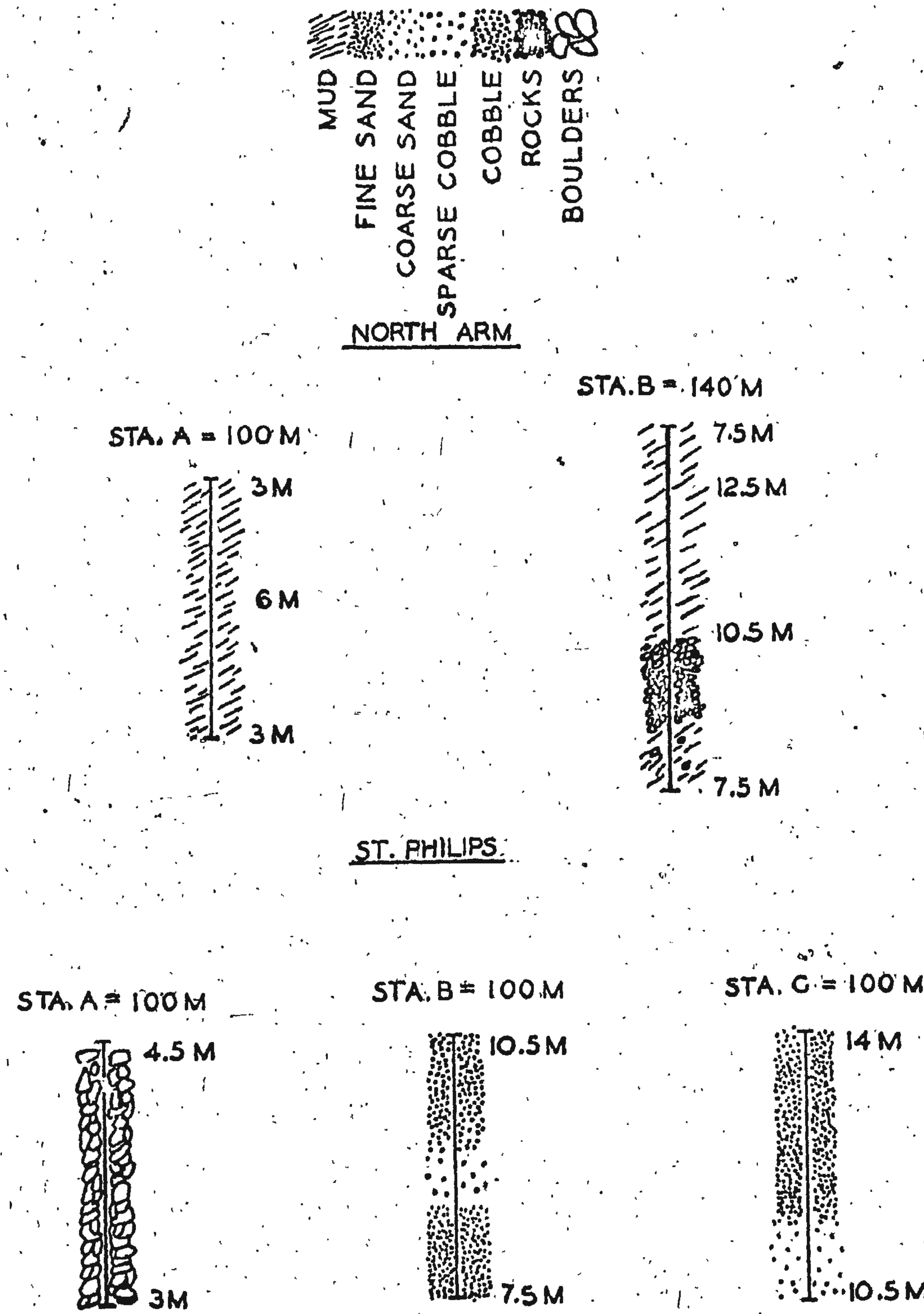
To overcome the problem of uneven distribution within a station permanent transects were established in North Arm Stations A and B and St. Philips Stations A and B in late April. Their positions are shown in Figures 2 and 3. Figure 5 gives their depths and bottom types. All transects were 100 m in length except for the one in North Arm Station B which was 140 m.

The following procedure was implemented to standardize the area surveyed during a transect count. A 3-m length of rope, the center of which was clearly marked, was stretched taut between two divers at a right angle to one end of the transect. The diver nearest the transect (always the author) was at a distance of 1-5 m from the transect, depending upon visibility. The divers then swam along the transect, each counting all winter flounders on the bottom between his end of the rope and its center mark. In this manner all fish in a strip 3 m wide and 100 m long (300 square meters; 420 square meters in North Arm Station B) were counted. This is defined as one count using the transect technique. Usually two such counts were made per dive, one on each side of the transect. As before, the poles were used to probe the bottom in North Arm but not in St. Philips.

The chief advantage of the transect technique was that a count of nonrandomly distributed winter flounders still gave a density figure

FIGURE 5

Bottom type, length, and depth range of each transect.


MUD
FINE SAND
COARSE SAND
SPARSE COBBLE
COBBLE
ROCKS
BOULDERS
NORTH ARM
STA. A = 100 M
3 M
6 M
3 M
STA. B = 140 M
7.5 M
12.5 M
10.5 M
7.5 M
ST. PHILIPS
STA. A = 100 M
4.5 M
3M
STA. B = 100 M
10.5 M
7.5 M
STA. C = 100 M
14 M
10.5 M

which was representative of a station. This is because the transects were of sufficient length and were so placed in each station that any concentration of flounders was likely to be encountered. Another major advantage was that in making a single count along a transect the bottom area surveyed was twice that of a single count using the portable quadrat, but both required the same amount of time.

3. Deeper Water Counts (Station D)

In Station D of both study sites a dive was made along a predetermined compass course and all winter flounders observed were counted. The number of fish observed in 30 minutes was used as a comparative density figure.

Immediately after the dives in North Arm Station D on June 22 and August 17 a region on the southern shore at the mouth of North Arm (Figure 2) was surveyed briefly by diving for winter flounders.

4. Frequency of Counts

Counts were usually made in North Arm and St. Philips on alternate weeks. Dives were made in the stations of a study site on successive days to decrease the effect on abundance figures caused by short-term flounder movement. Counts in St. Philips Stations B and C were usually made on the same dive. Only occasional dives were made in Station D of both study sites. Interruptions in this schedule were caused by drifting pack ice, principally in March and April, 1973, and by rough seas. During the period of drifting ice counts were made whenever the study sites were clear. A count postponed due to rough water was made as soon afterwards as possible. In St. Philips Station A counting was terminated on November 15 due to frequent breaking of the transect line by heavy seas, and to the absence of winter flounders there in October and November.

5. Statistical Analysis of Flounder Abundance

To determine if there were significant changes in the abundance of winter flounders present through the year the abundance data of each station was tested by an analysis of variance. Duncan's new multiple range test (Steel and Torrie, 1960) was used to determine which changes in abundance were significant in each station. The 0.05 protection level was used. The abundance data of North Arm Station A versus Station B and St. Philips Station B versus Station C were analyzed by X^2 to determine if these stations within study sites were homogeneous, i.e., if the patterns of change in abundance with time were similar. St. Philips Station A was omitted from the test because flounder abundance there was so low.

6. Tagging Experiments

An underwater tagging program was conducted in North Arm Stations A and B and St. Philips Stations B and C to aid in interpreting seasonal movements of winter flounders, and as an attempt to determine if more than one stock was present through the year in each study site. Flounders to be tagged were caught individually with a hand net. A dart tag (Floy Tag and Manufacturing, Inc.) was inserted with a tagging gun into the anterior dorsal musculature of the pigmented side of a fish. The tags were color coded for each station and a number was stamped on each tag. All tagging was done underwater, therefore several tagging dives were made in each station. No flounders were tagged in St. Philips Station A because of the scarcity of fish there. Since there is no commercial and little recreational fishing for flounders at either study site, returns were made by underwater sightings. These tagged fish were not collected.

B. Environmental Factors

On every dive that winter flounders were counted the following factors were recorded: (1) time of day, (2) state of the tide (from the time of the dive and tide tables of the Canadian Hydrographic Service), (3) cloud cover (clear, slightly cloudy, cloudy, very cloudy), (4) turbidity of the water (clear, slightly turbid, turbid, very turbid; after Warfel and Merriman, 1944), (5) bottom salinity (measured by refractometer to the nearest 0.5 parts per thousand), and (6) bottom water temperature (to the nearest 0.5° C). Dates on which counting was prevented by ice, and dates of severe storms, were recorded. Wind information was obtained from the monthly meteorological summaries for the St. John's Airport, prepared by the Atmospheric Environment Service, Department of the Environment. In these summaries the speed and direction of peak gusts were usually recorded every day. The percentage of days per month with peak gusts of 40 miles per hour (64 km/h) or greater and 50 miles per hour (80 km/h) or greater were used to indicate relative wind speeds each month. The percentage of days per month with northerly, easterly, and northeasterly components respectively to the peak gusts were calculated from the meteorological summaries for comparative purposes.

C. Physiological Factors

On each date that counts were made a sample of winter flounders was taken by hand net. The sample sizes were generally small (Appendices C and E) and were restricted by the number of fish available, the limitation of diving time, and the coldness of the divers. All fish in a sample were killed by a blow on the back of the head immediately after each dive and placed on ice for approximately 1-2 hours. They were then frozen for 1-7 days. After thawing by submersion in water the following data were obtained from each fish: (1) total length, (2) blotted body weight, (3) sex, (4) gonad weight, (5) the reproductive stage of the gonads, and (6) the fullness of the intestine. The stomach was removed and preserved in formalin.

1. Body Weight Analysis

A method was required to denote changes in body weight by the stocks of winter flounders in North Arm and St. Philips to relate movements to feeding. In each study site mature flounders taken from all stations combined were divided by sex and grouped into time intervals of 1-3 months depending upon the number of fish in each group. Abnormal fish, such as ones obviously sick or ones not going to spawn in 1973, were excluded. The lengths and weights of the fish in these groups (time intervals) were compiled, and the data of each sex in each study site were analyzed by an analysis of covariance (making four runs). In each run this analysis eliminated the variability among the mean weights of the groups due to differences in length composition, resulting in an adjusted mean weight for each group. An F value was given in each run to indicate if there were significant differences in the adjusted mean weights of the groups.

For both sexes in both study sites Duncan's new multiple range test (Steel and Torrie, 1960) was used to determine which changes in the adjusted mean weights with time were significant. The 0.05 protection level was used.

2. Reproduction

The reproductive cycle of the mature winter flounder can be classified into four stages: ripening, ripe, spent, and resting. These stages are defined in Table 2. The distinction between large ripening and ripe gonads in both sexes was not realized until late in the season, therefore from January to June, 1973 ripening fish were wrongly identified as ripe. Therefore for purposes of presentation the mature flounders are classified into three reproductive stages: (1) ripening or ripe, (2) spent, and (3) resting.

Gonad growth was also examined by using the gonosomatic index (gonad weight expressed as a percentage of the total body weight).

3. Food and Seasonal Feeding Behaviour

There are several widely used methods for analyzing the food and seasonal feeding habits of fishes. These were well reviewed by Hynes (1950) and Reintjes and King (1953), and to a lesser extent by Ball (1961), Jones (1952), and Kennedy (1964). Various combinations of these techniques were used to study the feeding habits of *P. americanus* by Kennedy (1964), Kennedy and Steele (1971) Merriman and Warfel (1948), Olla *et al.* (1969), Pearcy (1962), Richards (1963), and

TABLE 2

Reproductive stages of the winter flounder

Male	Female
Immature	
- testes are very small, and vas deferens is very narrow; coelom has little or no space to accommodate enlarged testes.	- ovaries are small and oviducts are very narrow; coelom has little or no space to accommodate enlarged ovaries.
Mature	
- testes are larger and vas deferens has a wider diameter; space is available in coelom to accommodate enlarged testes.	- ovaries extend quite far back into coelomic cavity, and oviducts have a relatively large diameter; space is available in coelom to accommodate enlarged ovaries.
Ripening	
- testes are enlarging, rather white in color, and are soft and flexible.	- ovaries are enlarging, yellow or orange, and are firm; vitellogenesis has begun (yolk globules present in eggs).
Ripe	
- testes are very large, white, soft and flexible; sperm is present in the vas deferens (and can be extruded under pressure - Kennedy, 1964).	- ovaries are very large and are rather clear and colorless; eggs are transparent (and can be extruded under pressure - Kennedy, 1964).
Spent	
- testes are still large but deflated, maybe grey in color, and are exhausted looking; some sperm may remain in testes or vas deferens.	- ovaries are large but deflated, clear or reddish, soft and flaccid and exhausted looking.
Resting	
- testes are small, grey and hard.	- ovaries are quite small, reddish or clear (maybe yellowish), and firm.

Wells *et al.* (1973). Since the degree of fullness of the stomachs and the mean volume of food per stomach in a sample indicate seasonal changes in feeding intensity (Ball, 1961), these indices were chosen for the present study together with a third, the degree of fullness of the intestine.

a. Stomach fullness index. The degree of fullness of a stomach (stomach fullness index) is a point system used by Ball (1961). His description of the system is as follows:

Empty	Stomach collapsed, no food present	0 points
¼ full	Food occupying about ¼ of the total volume of the stomach. Wall feels thick and hard when pressed between forceps.	1 point
½ full	Stomach containing food, generally along most of its length, but the inner surface is longitudinally pleated and the wall feels thick and hard between forceps.	2 points
3/4 full	Stomach nearly filled with food, but some space remains and a small region of the wall feels thick and hard, with shallow longitudinal pleats internally.	3 points
Full	Stomach full. Internal longitudinal pleats shallow or absent. Entire wall feels soft and can be indented with forceps in the intact stomach.	4 points
Distended	Stomach packed with food. Wall cannot be pinched with forceps in the intact stomach, and is thin and stretched with no internal pleating.	5 points

In the present study the first consideration in designating points to a stomach was the amount of food present, and the second consideration was the condition of the stomach rugae and thickness of the stomach wall. The stomach fullness indices of all stomachs in a sample (or group of samples) were averaged and rounded to the nearest whole number to give the mean stomach fullness (M. S. F.). An advantage of the mean stomach fullness is that variability due to fish size is eliminated (unless fish of different sizes are feeding at different intensities). Since the stomach fullness index of each fish is a visual estimate it is not a precise measurement. However, it was found to be suitable for purposes of comparison.

b. Intestinal fullness index. Soon after flounders began feeding in May it was occasionally noted that food was present in the intestine, but not in the stomach. Since the stomach fullness index would not give an accurate representation of feeding in these fish, the intestinal fullness index, also a point system, was developed. The point designation of the intestinal fullness index was as follows:

Intestine empty or very nearly empty	0 points
Intestine with some food present	1 point
Intestine approximately ½ full	2 points
Intestine nearly full	3 points
Intestine full or distended	4 points

The intestinal fullness indices of all fish in a sample (or group of samples) were averaged and rounded to the nearest whole number to give the mean intestinal fullness (M. I. F.). Though the intestinal fullness index was intended only as a rough check on the stomach fullness index, the two indices were very similar in describing seasonal changes in feeding intensity.

c. Mean volume. After estimating the stomach fullness index of a given stomach its contents were sorted under a binocular microscope into the taxonomic groups listed in Appendices G-K. Each group of organisms was pressed onto filter paper to remove excess fluids and then its wet volume was measured to the nearest 0.05 cc by water displacement in a burette. If a group of food organisms had a volume of less than 0.05 cc, it was not recorded. The volumes of all groups were added to give the total volume of food present in the stomach. The volumes of food in all stomachs in a sample (or group of samples), including empty stomachs, were averaged to give the mean volume (M. V.). This method was also used by Kennedy (1964) and Kennedy and Steele (1971) in studying seasonal changes in feeding in *P. americanus*. There are two major sources of variation in volumetric determinations. One is fish size and its relationship to the amount of food eaten. Obviously a large fish will eat a greater volume of food than a small fish. The other source of variation is an opportune but restricted food supply which can result in consumption of food in much greater quantities than would normally be expected. For these reasons it is felt that the mean stomach fullness and mean intestinal fullness were more indicative of seasonal changes in feeding intensity than was the mean volume.

d. Food organisms. To indicate the relative importance of the various groups of food organisms the percentage volume of each group per sample (the aggregate-total-volume method of Reintjes and King, 1953) was derived from this equation:

$$\%\ \text{volume/sample} = \frac{\text{volume of an organism from all stomachs in a sample}}{\text{total volume of all stomachs in the sample}}$$

A drawback to the data on food organisms is the large percentage volume per sample of unidentifiable organic matter found in the stomachs (Appendices G-K). This has not been reported in previous studies of feeding in the winter flounder. Since winter flounders in the present study were placed on ice, frozen, and thawed before the stomachs were removed and placed in formalin, it is apparent that digestion of the stomach contents continued after capture. This is the probable cause of the large amounts of unidentified organic matter in the stomachs of fish collected during the feeding season. But this digestion should have had little effect on the mean stomach fullness or mean volume values obtained.

Similar unidentifiable organic matter was found in the stomachs of fish collected during times of the year when they were not feeding. This accounts for mean stomach fullness values between 0 and 1 and for mean volumes greater than 0 during these periods.

To summarize, seasonal changes in feeding intensity were determined by changes in the mean stomach fullness (M. S. F.), mean intestinal fullness (M. I. F.), and mean volume (M. V.). Relative importance of the different groups of food organisms is indicated by the percentage volume of an organism per sample (% volume/sample).

III. RESULTS

A. Environmental Factors

All dives were made between 11:00 A. M. and 5:15 P. M. at various stages throughout the tidal cycle. The degree of cloud cover followed no seasonal pattern, though the majority of days were recorded as cloudy or very cloudy. The waters in both study sites were generally clear or slightly turbid in the winter, and slightly turbid in the spring. In the summer and fall the waters of North Arm were usually turbid or very turbid, while those of St. Philips were slighly turbid or turbid.

Salinity of the bottom water in North Arm was usually 32-33 parts per thousand in winter and spring, and 31-31.5 parts per thousand in summer and fall. Two relatively low values were recorded in Station A on February 22, 1973 (30.5 parts per thousand) and on August 14 (29.0 parts per thousand). Salinity values in St. Philips were usually 32-33 parts per thousand in winter and summer, and 31-31.5 parts per thousand in spring and fall.

Bottom temperatures are given in Figures 6 and 7 and Table 3. In North Arm they ranged from -1.0° C in late winter and early spring to 13.0° C in late summer and early fall. The range in St. Philips was -1.5 to 13.5° C. Seasonal changes in bottom temperature in North Arm and St. Philips were quite similar.

Winds were very strong in the winter and early spring, and were of noticeably lower velocity from spring to mid-fall (Figure 8). They were much stronger in the winter of 1974 than in 1973. Northerly

FIGURE 6

North Arm: bottom temperature (to nearest 0.5°C) recorded on each dive.

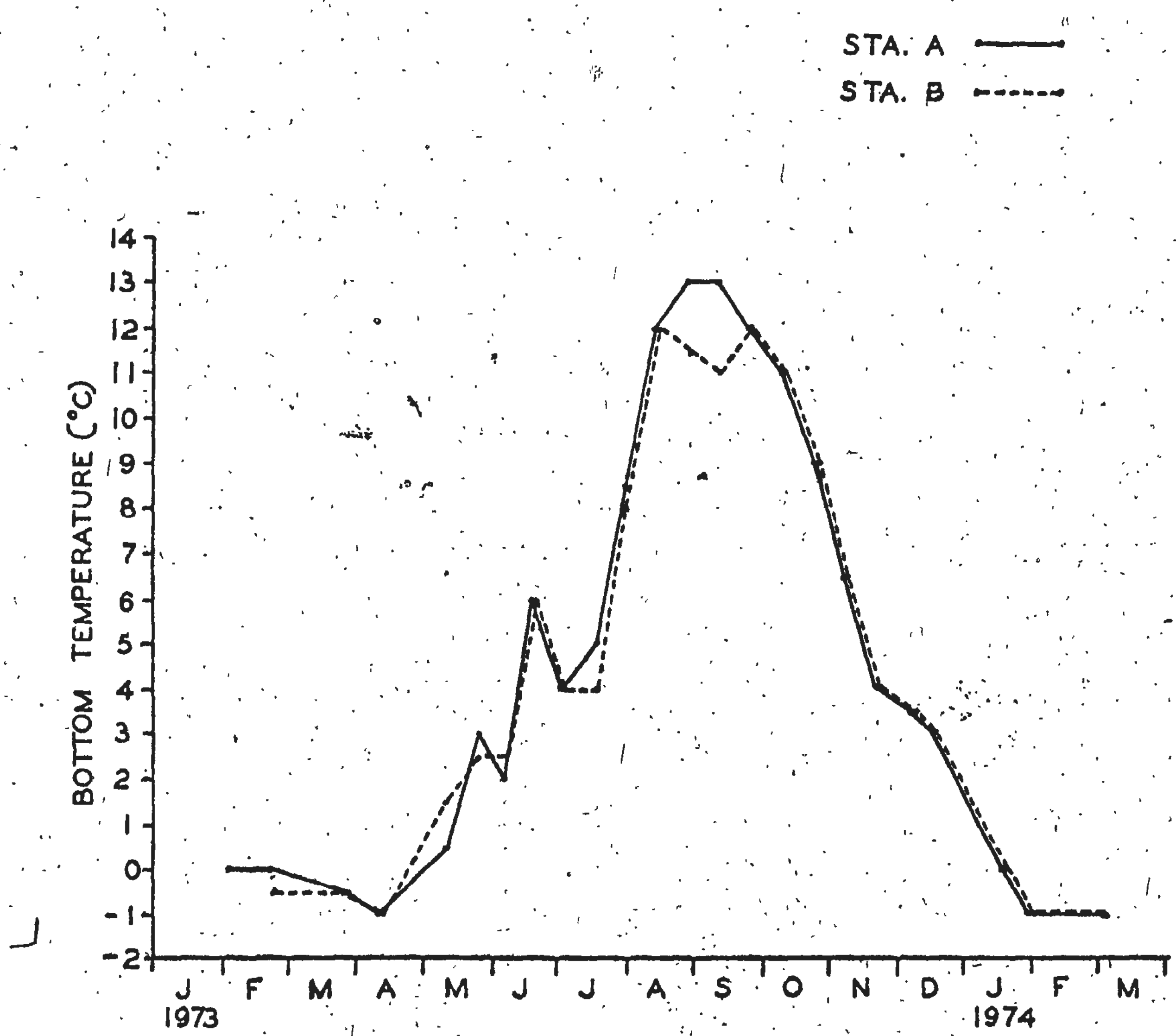

STA. A
STA. B
BOTTOM TEMPERATURE (°C)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
J F M A M J J A S O N D J F M
1973
1974

FIGURE 7

St. Philips: bottom temperature (to nearest 0.05°C) recorded on each dive.

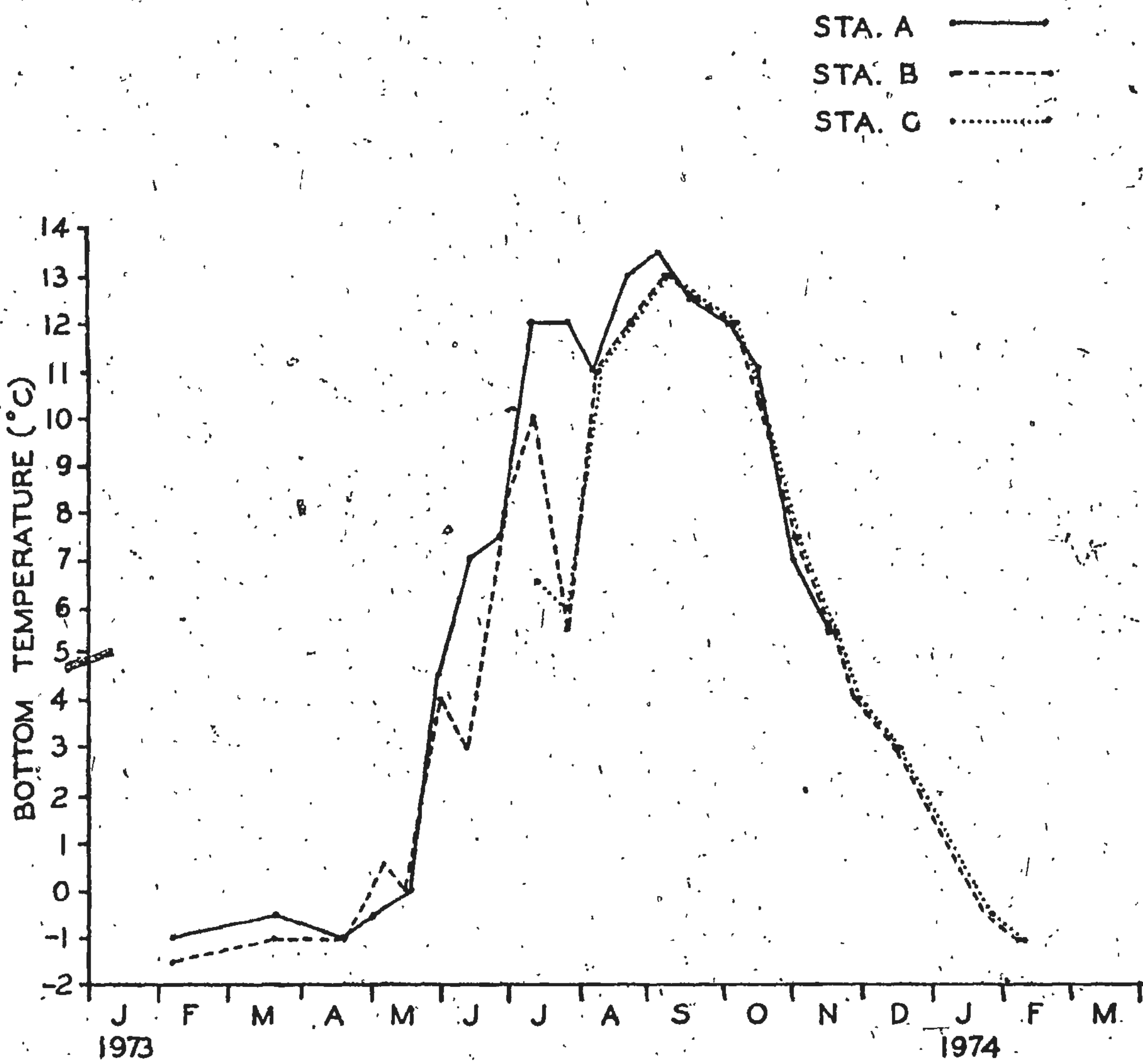
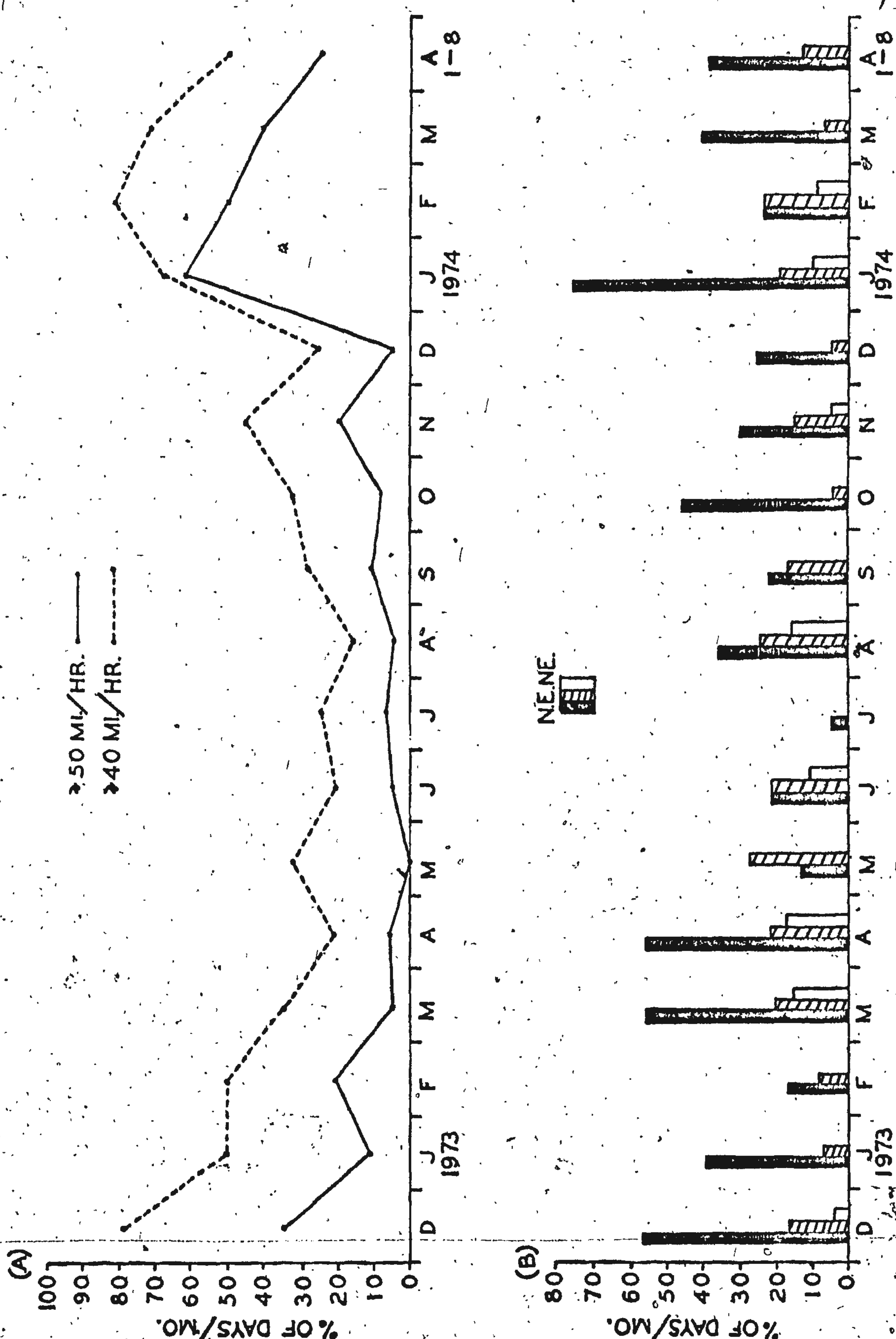

STA. A
STA. B
STA. C
BOTTOM TEMPERATURE (°C)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
1973
1974

FIGURE 8

Wind speed and direction: the percentage of days per month (a) with peak gusts of 50 miles per hour (80 km/hr) or greater and 40 miles per hour (64 km/hr) or greater, and (b) with a northerly, easterly, and northeasterly component to the peak gusts.



(A)
% OF DAYS/MO.
100 90 80 70 60 50 40 30 20 10 0
≥50 MI/HR.
≥40 MI/HR.
D J F M A M J J A S O N D J F M A
1973
1974
1–8
(B)
% OF DAYS/MO.
80 70 60 50 40 30 20 10 0
N.E.
NE.
D J F M A M J J A S O N D J F M A
1973
1974
1–8

TABLE 3

Bottom temperature (to nearest 0.5° C) recorded on each dive in Station D of both study sites.

Date	North Arm Station D	St. Philips Station D
March 21		-
April 13	-1.0	
June 1		-1.0
June 22	0.0	
August 17	9.0	
August 24		9.5
September 10		13.0
November 30		4.0

winds occurred frequently.

Pack ice, which formed much further north and was moving past the Newfoundland coast, drifted into and out of the shore zone with changing winds through March and April, 1973. Winds were not strong during this period but the percentage of days with easterly and north-easterly gusts was relatively high, jamming the drifting ice into North Arm and St. Philips. Diving in North Arm was prevented by ice on March 7-10, March 30, and April 19-26. This occurred in St. Philips on February 27 - March 6, March 12-16, April 3-6, and April 17. The ice extended deep into the water column. That of April 19-26 gouged the bottom in North Arm Station A. In St. Philips there was no observed evidence of ice scraping the bottom, though this undoubtedly occurred in Station A. The ice probably came quite close to the bottom in Station B.

Severe storms occurred during the fall, causing much turbulence. In North Arm the turbulence resulted in high turbidity and scouring of the bottom in the shallower regions. In St. Philips the turbulence produced sizeable ridges in the sand. The approximate dates of the storms were October 10/11, November 21/22, November 24-28 (the worst of the season), and December 3-5.

B. Physiological Factors

1. Body Weight Analysis

The results of the analysis of covariance and Duncan's new multiple range test on the length-weight data of each sex in each study site are given in Figures 9 and 10 and Appendices A and B. The adjusted mean weights of male and female wihter flounders from North Arm and St. Philips were low in early summer. By late summer and early fall the adjusted mean weights of both sexes in both study sites had increased. The weights of North Arm males and St. Philips males and females reached a peak in October; the weight of the North Arm females decreased insignificantly. In late fall the weights of both sexes in both study sites decreased to a low level. No winter flounders were collected in St. Philips in January to March, 1974, but those taken from North Arm during this period were significantly heavier than fish collected in December.

2. Reproduction

For each sample of winter flounders (sexes combined) the percentage of fish in each stage of reproduction was determined. The gonosomatic indices of the fish were tabulated in two ways:

FIGURE 9

North Arm (all stations combined): adjusted mean weight of each sex divided into intervals of time. Adjusted mean weights are from the analysis of covariance of the length-weight data. S(= significant at the 0.05 protection level) shows significant changes in adjusted mean weight between adjacent time intervals. (a) males, (b) females (from Appendix A).

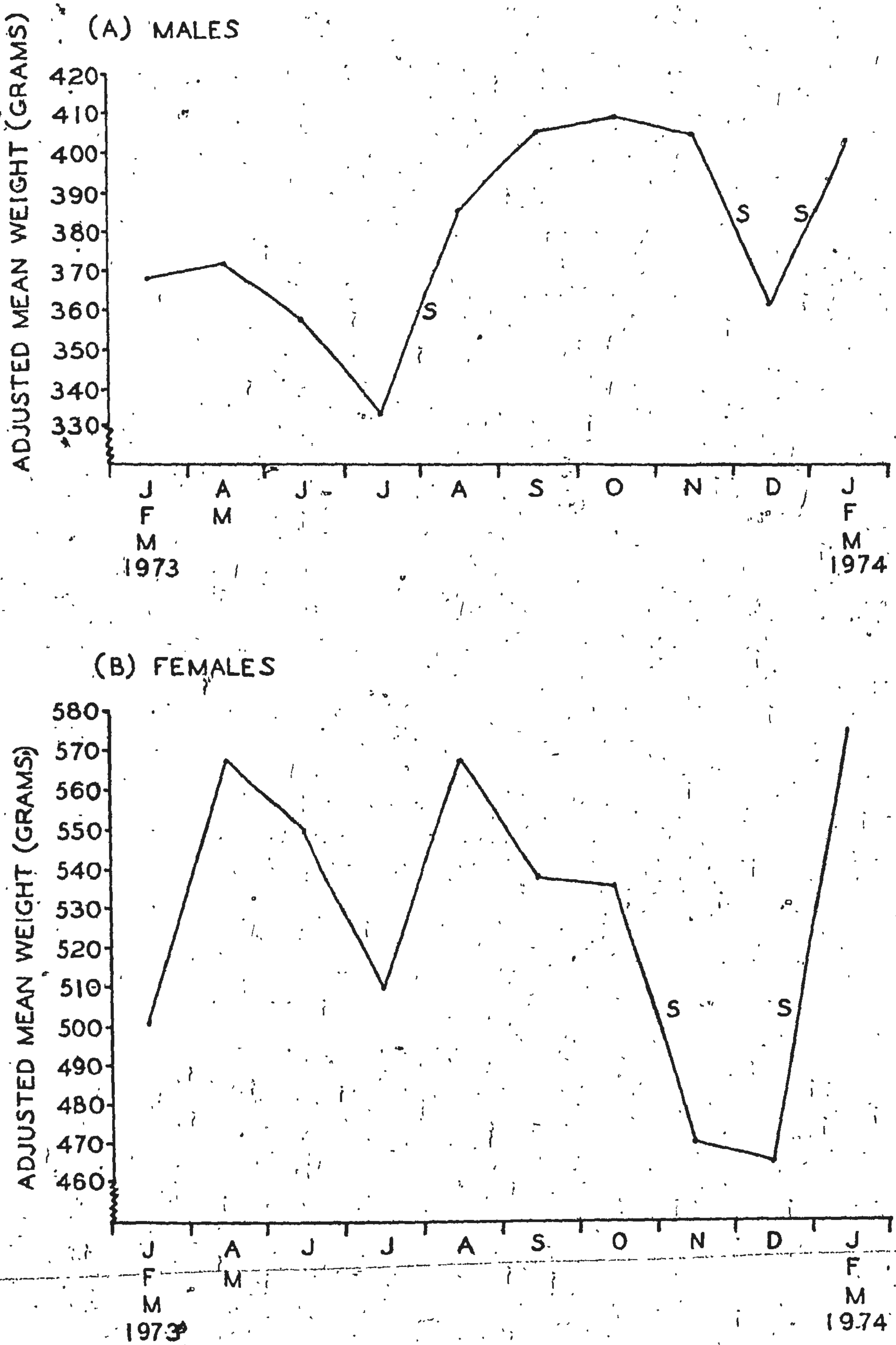
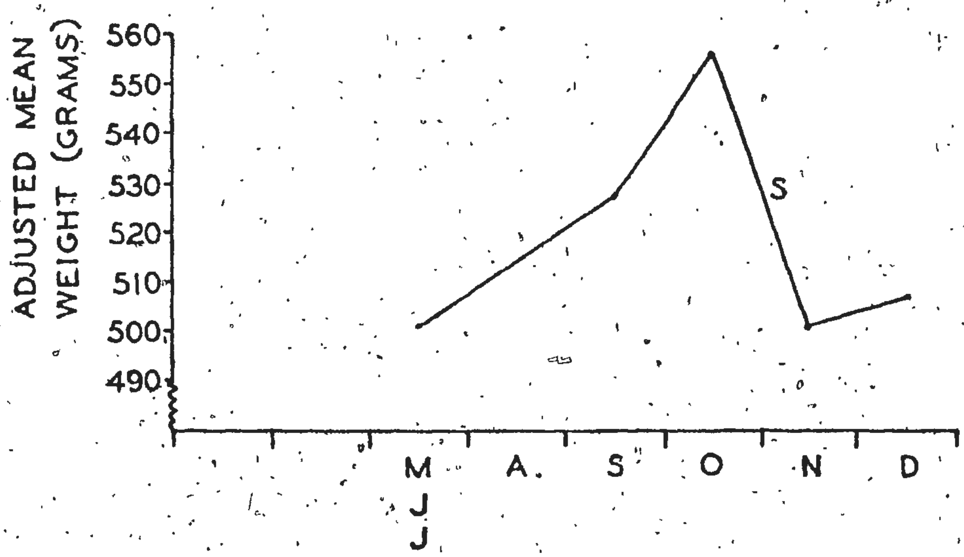

(A) MALES
ADJUSTED MEAN WEIGHT (GRAMS)
420
410
400
390
380
370
360
350
340
330
S
S
S
J F M 1973
A M
J
J
A
S
O
N
D
J F M 1974
(B) FEMALES
ADJUSTED MEAN WEIGHT (GRAMS)
580
570
560
550
540
530
520
510
500
490
480
470
460
S
S
J F M 1973
A M
J
J
A
S
O
N
D
J F M 1974

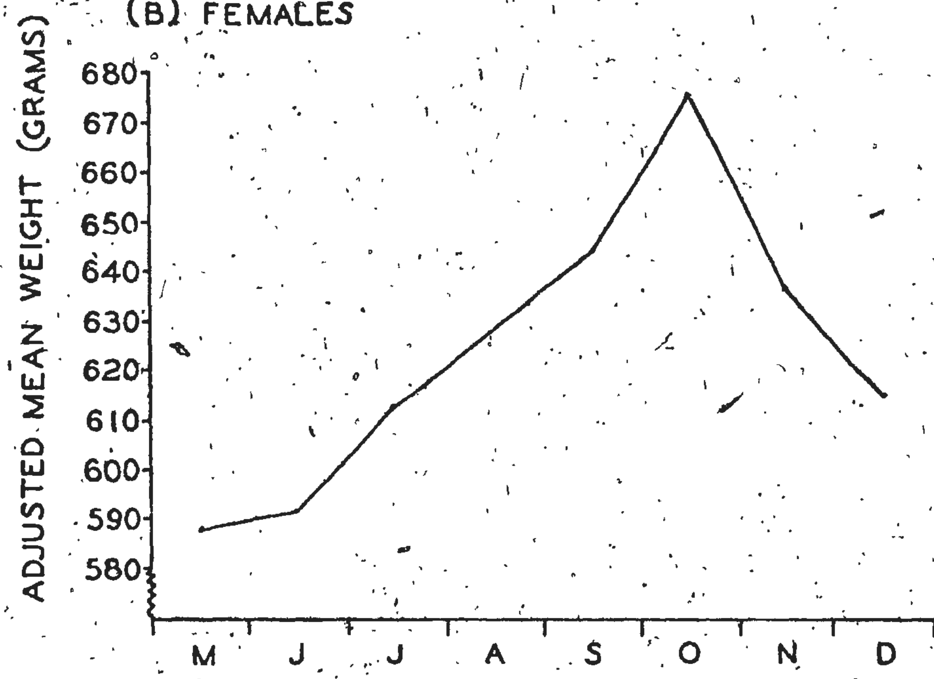
FIGURE 10

St. Philips (all stations combined): adjusted mean of each sex divided into intervals of time. Adjusted mean weights are from the analysis of covariance of the length-weight data. S (= significant at the 0.05 protection level) shows significant changes in adjusted mean weight between adjacent time intervals. (a) males, (b) females (from Appendix B).

(A) MALES



(B) FEMALES



(1) individual samples were divided by sex and the average gonosomatic index was determined for each, and (2) within each study site mature fish from all stations combined were divided by sex and grouped into intervals of time. The average gonosomatic index was then determined for each sex in each group. These groups of flounders correspond to those in the analysis of the body weight data, for which this grouping was established. In both of these methods of treatment flounders which were not undergoing spawning in 1973 were omitted from the computation of the average gonosomatic index.

Though the sizes of the samples collected were small (Appendices C-F), the results clearly indicate seasonal trends in the reproductive cycle of the winter flounder. In North Arm flounders were ripening or ripe from late January, when the survey began, until early June (Figure 11). Figures 12 and 13 show that the gonads of both sexes were at or near maximum size during this period. The first spent fish was collected in North Arm on May 24 in Station A, but the great majority of fish spawned in June. All flounders collected on July 3 were spent. Through July the fish were spent or resting, and all were resting by August. The gonosomatic index of both sexes was at a minimum in July and August. In late August the first ripening flounders were recovered (approximately half of each sample), and by September nearly all were ripening. This is clearly indicated in both sexes by the gonosomatic index. Winter flounders in North Arm continued to ripen until the survey ended in March, 1974. Figures 12 and 13 show that the males may have ripened more quickly than the females. The gonosomatic index of the males reached a peak in October, declined

FIGURE 11

North Arm: the percentage of each sample of winter flounders in each stage of reproduction. (a) Station A, (b) Station B.

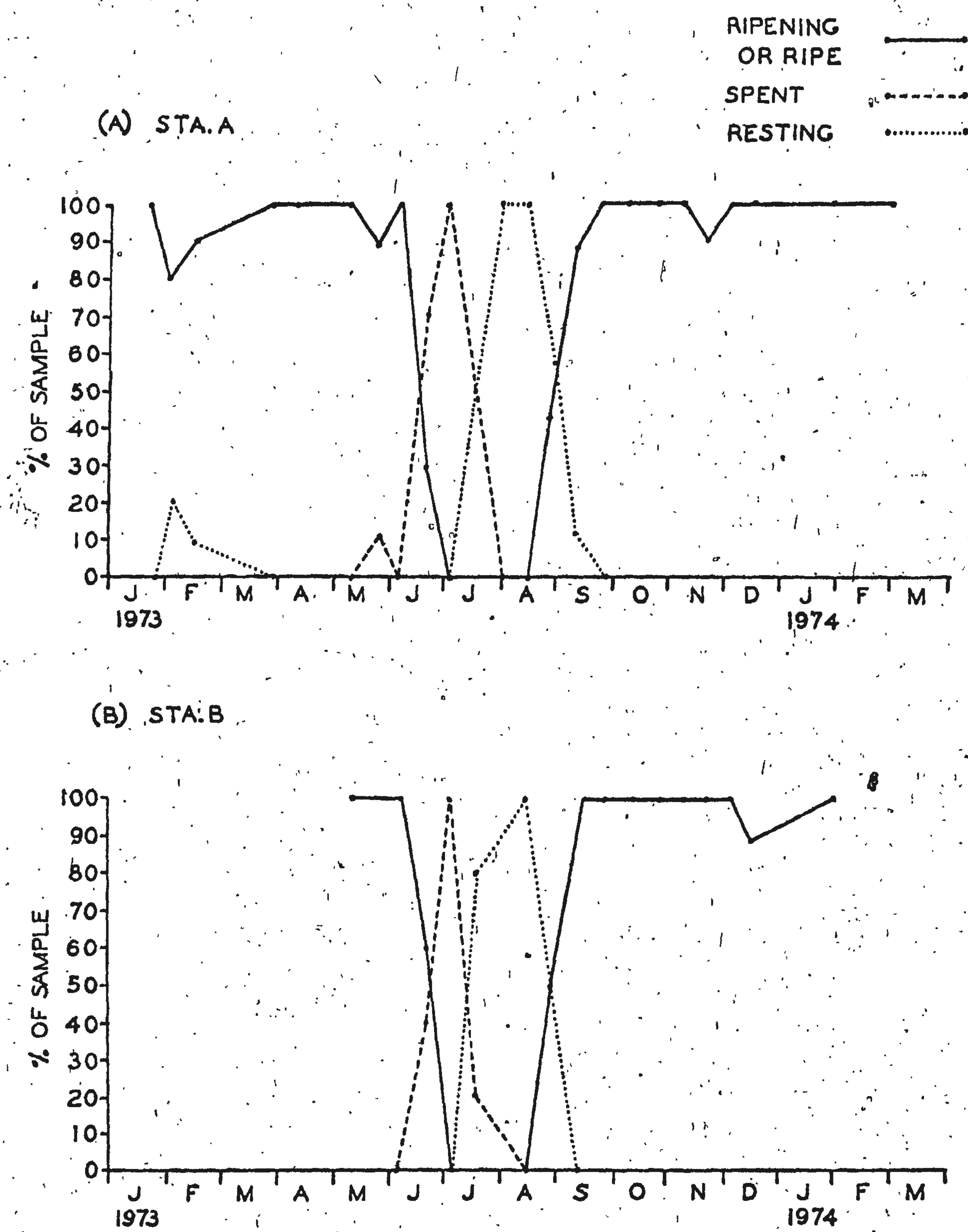

RIPENING OR RIPE
SPENT
RESTING
(A) STA. A
100
90
80
70
60
50
40
30
20
10
0
% OF SAMPLE
J F M A M J J A S O N D J F M
1973
1974
(B) STA. B
100
90
80
70
60
50
40
30
20
10
0
% OF SAMPLE
J F M A M J J A S O N D J F M
1973
1974

FIGURE 12

North Arm: average gonosomatic index (G.S.I. = gonad weight/body weight x 100) for each sex in each sample. (a) Station A, (b) Station B (from Appendix C).

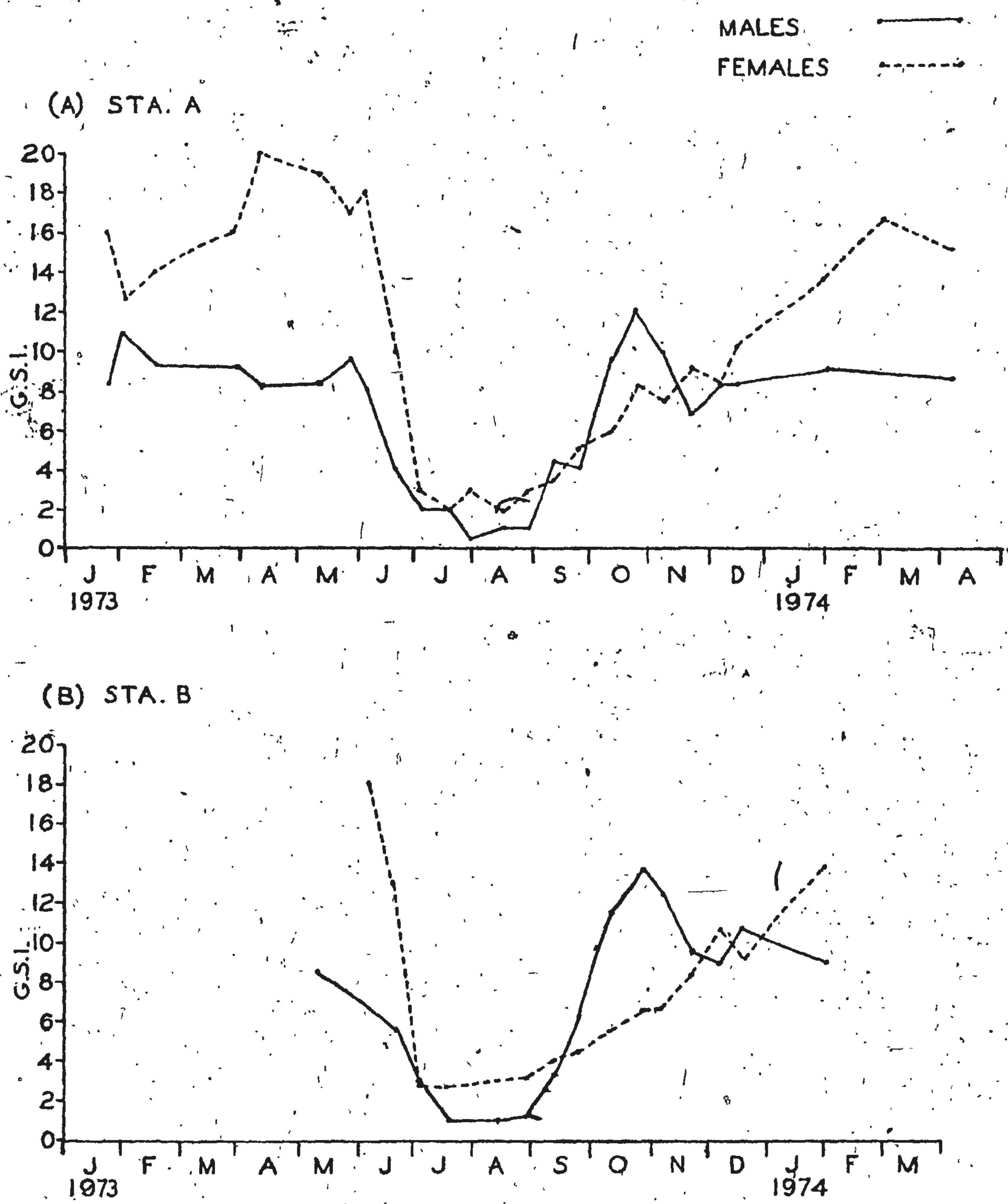
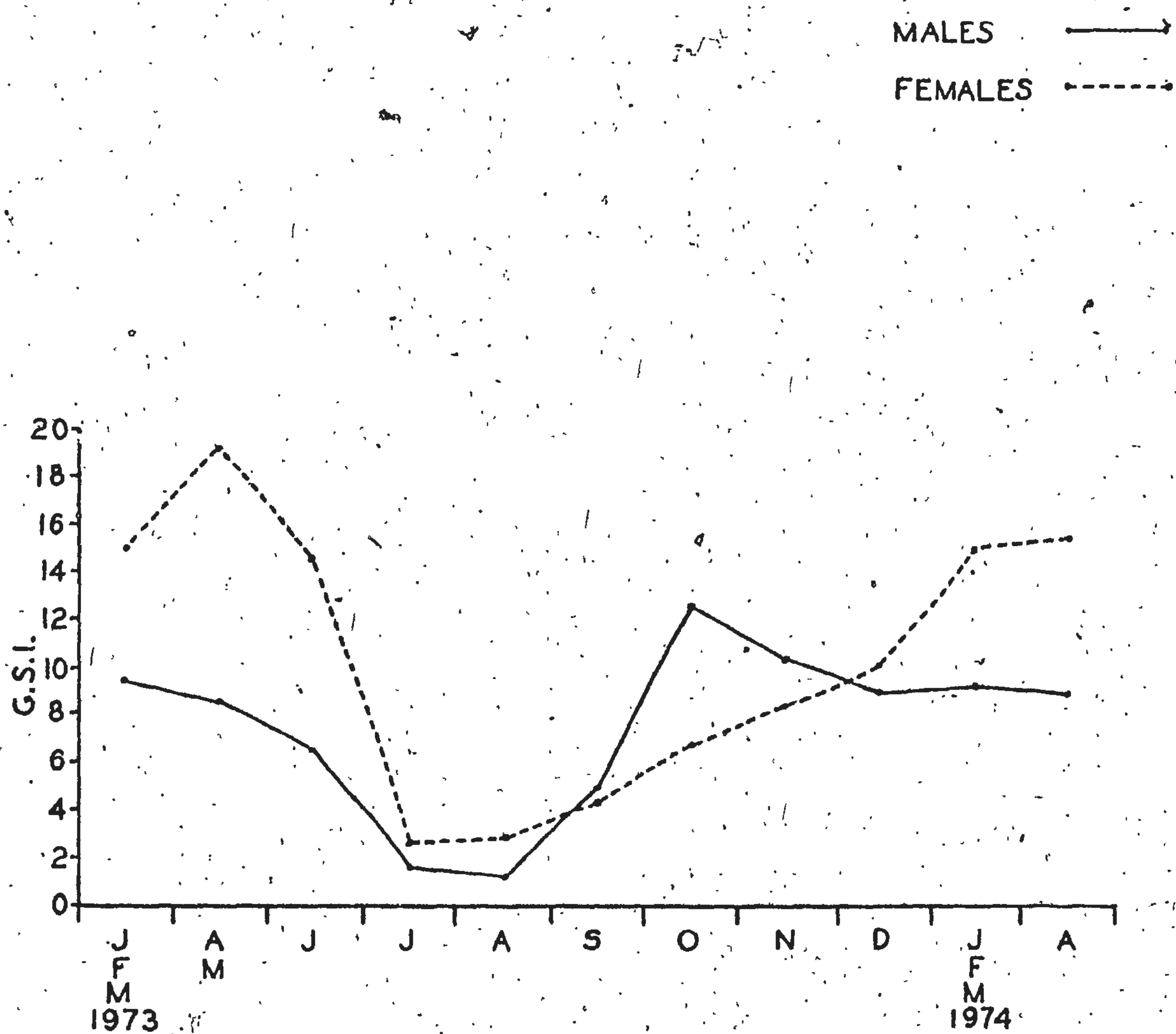

MALES
FEMALES
(A) STA. A
G.S.I.
0 2 4 6 8 10 12 14 16 18 20
J F M A M J J A S O N D J F M A
1973
1974
(B) STA. B
G.S.I.
0 2 4 6 8 10 12 14 16 18 20
J F M A M J J A S O N D J F M
1973
1974

FIGURE 13

North Arm (all stations combined): average gonosomatic index (G.S.I. = gonad weight/body weight x 100) for each sex divided into intervals of time (from Appendix D).


MALES
FEMALES
G.S.I.
20
18
16
14
12
10
8
6
4
2
0
J F M 1973
A M
J
J
A
S
O
N
D
J F M 1974
A

somewhat in November and then remained relatively steady; that of the females increased gradually throughout the fall and winter. Kennedy (1964) and Kennedy and Steele (1971) reported a similar occurrence in Long Pond, Newfoundland.

Winter flounders were first collected from St. Philips in May. The majority of these fish were ripening or ripe, but a few were spent (Figure 14). This was also true in earlier June. By late June the few fish collected were all spent. Their gonads changed from a spent to a resting condition in July, at which time the gonosomatic index of both sexes was at a minimum (Figures 15 and 16). Flounders were absent from St. Philips in August, thus none were collected. In early September, when they began to return to St. Philips, most were in the early stages of ripening, and they continued to ripen through mid-December, which was the last date fish were collected. As in North Arm and Long Pond (Kennedy, 1964; Kennedy and Steele, 1971), the males appear to have ripened more quickly than the females (Figures 15 and 16).

3. Food and Seasonal Feeding Behaviour

Olla *et al.* (1969) reported a diurnal variation in feeding activity in *P. americanus*. They found that feeding most likely occurred throughout the day and ended just before evening twilight. Their evidence indicated that there was no food intake at night. Since all fish in the present study were collected between 11:00 A. M. and 5:15 P. M., the time of day of collection probably had little effect on the feeding analyses.

FIGURE 14

St. Philips: the percentage of each sample of winter flounders in each stage of reproduction. (a) Station A, (b) Station B, (c) Station C.

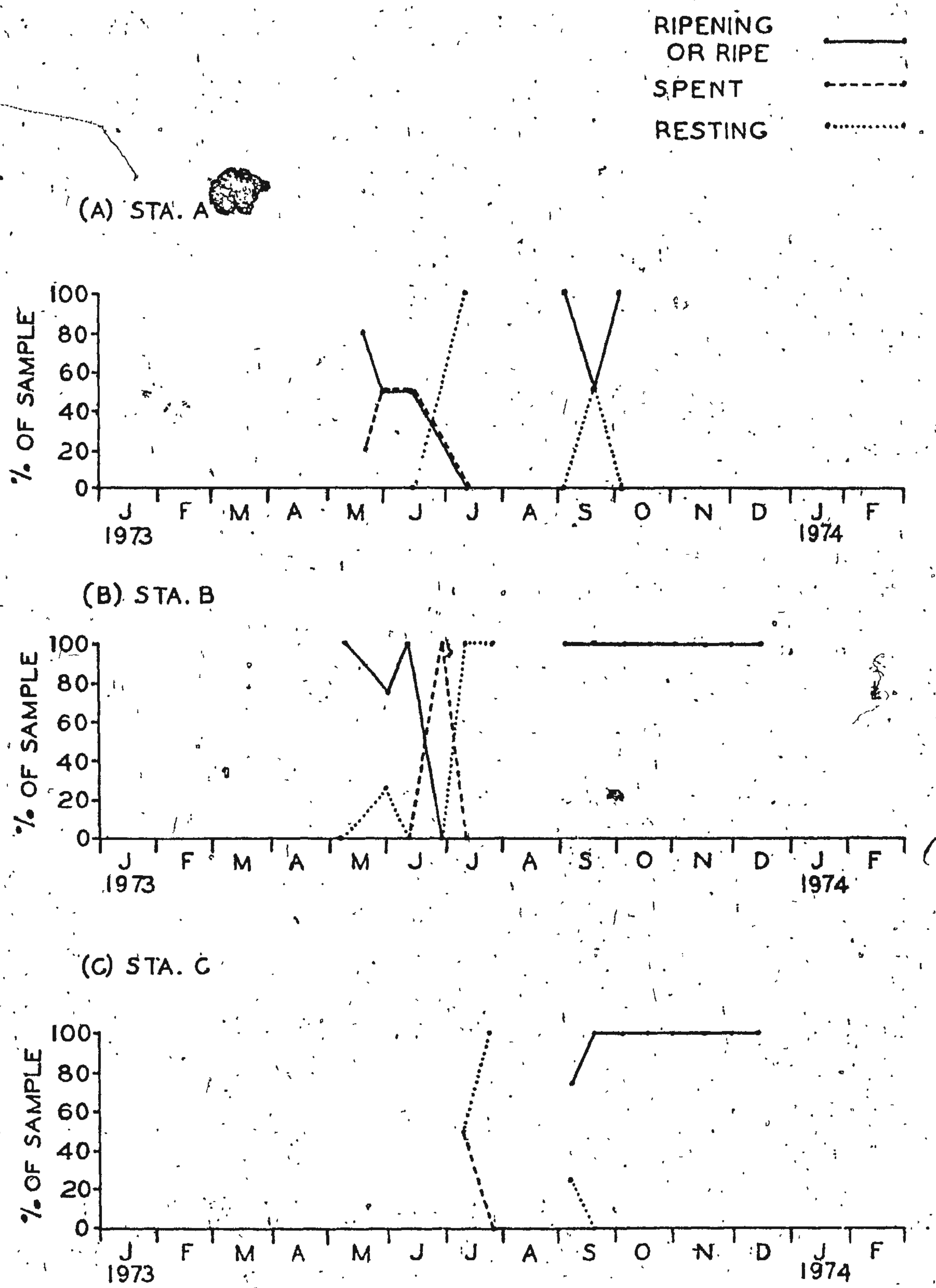
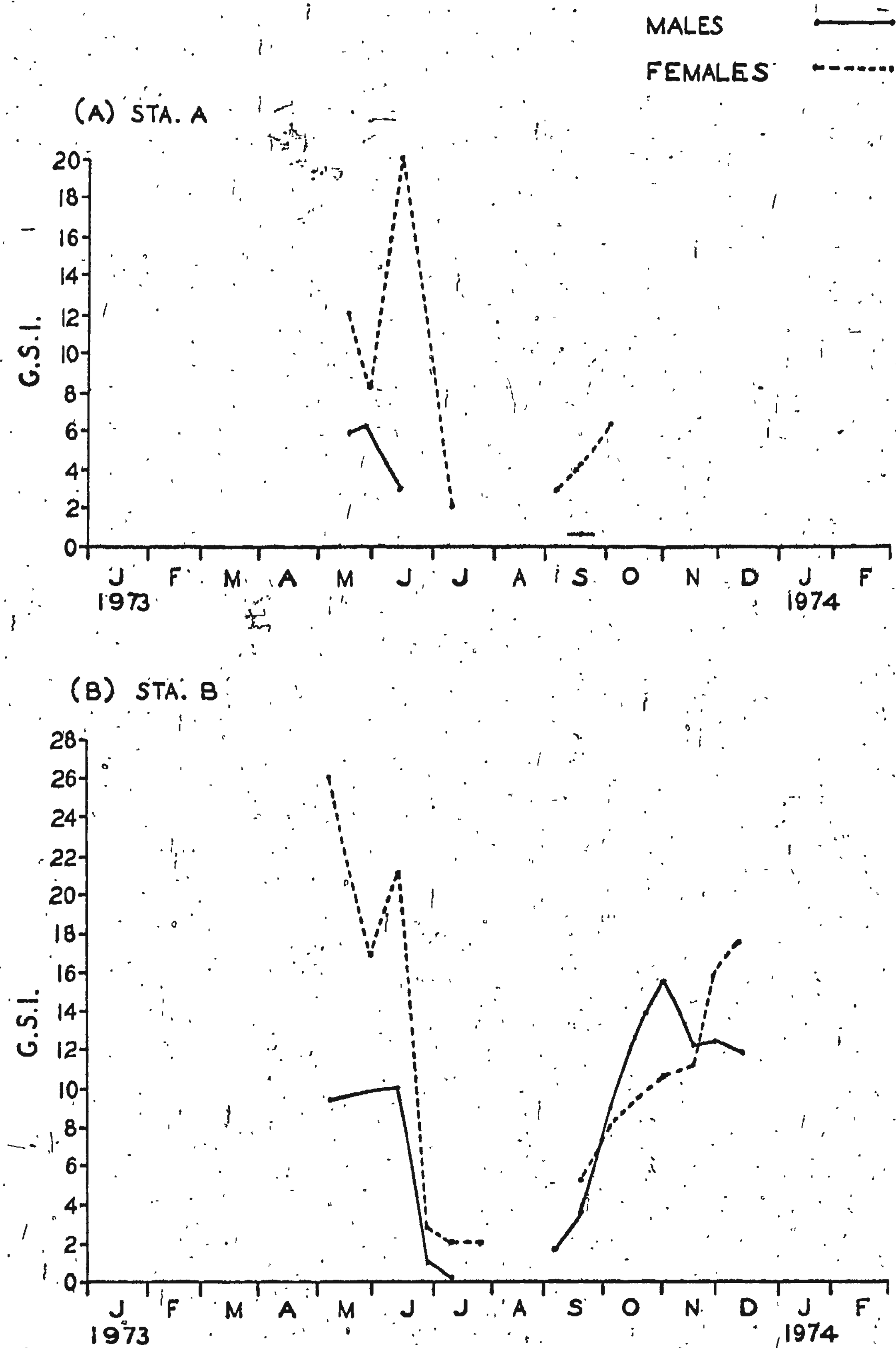

RIPENING OR RIPE
SPENT
RESTING
(A) STA. A
% OF SAMPLE
100
80
60
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
J
F
1973
1974
(B) STA. B
% OF SAMPLE
100
80
60
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
J
F
1973
1974
(C) STA. C
% OF SAMPLE
100
80
60
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
J
F
1973
1974

FIGURE 15

St. Philips: average gonosomatic index (G.S.I. = gonad weight/body weight x 100) for each sex in each sample. (a) Station A, (b) Station B, (c) Station C (from Appendix E).


MALES
FEMALES
(A) STA. A
G.S.I.
0
2
4
6
8
10
12
14
16
18
20
J F M A M J J A S O N D J F
1973
1974
(B) STA. B
G.S.I.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
J F M A M J J A S O N D J F
1973
1974

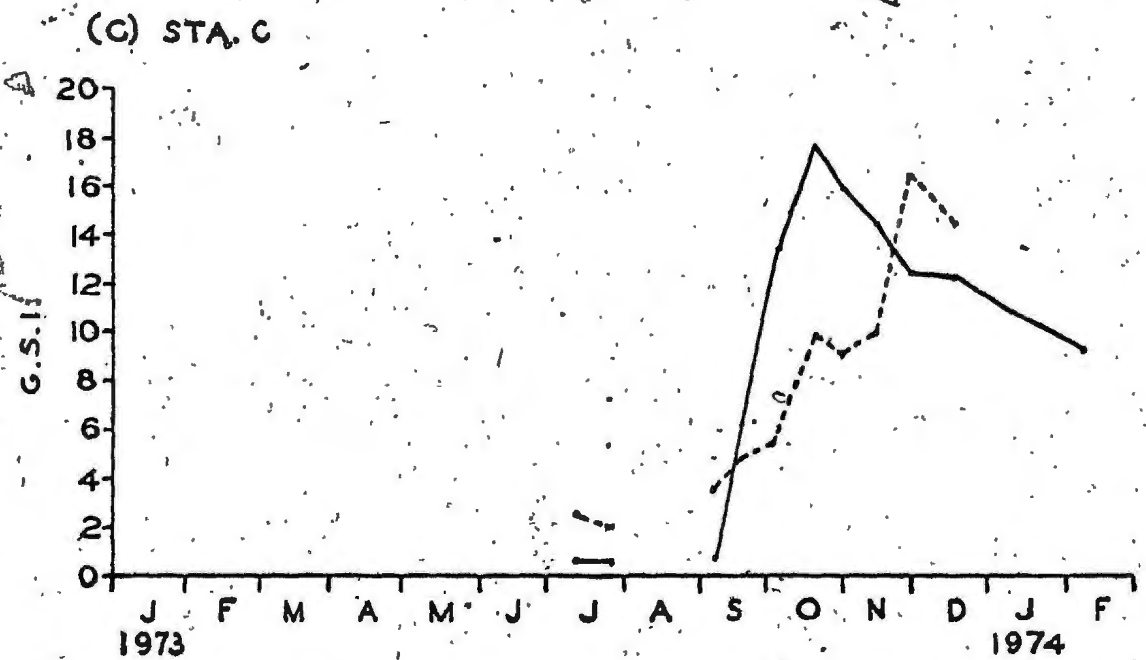
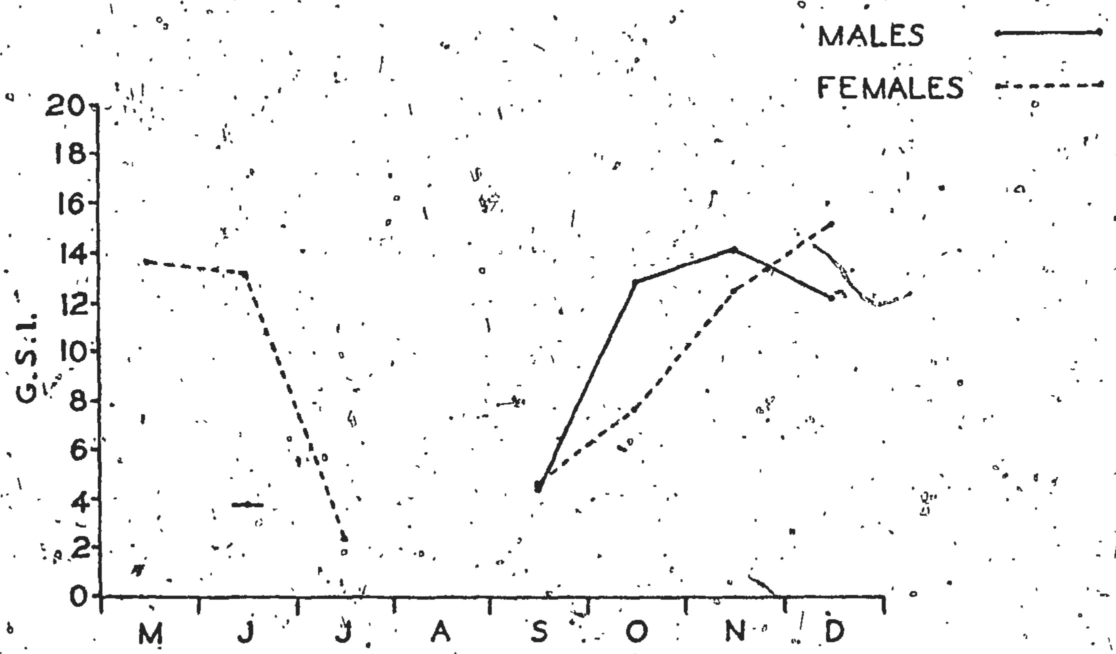

(C) STA. C
G.S.I.
20
18
16
14
12
10
8
6
4
2
0
J F M A M J J A S O N D J F
1973
1974

FIGURE 16.

St. Philips (all stations combined): average gonosomatic index (G.S.I. = gonad weight/body weight x 100) for each sex divided into intervals of time. May, June, and July are combined in the males (from Appendix F).


MALES
FEMALES
G.S.I.
20
18
16
14
12
10
8
6
4
2
0
M
J
J
A
S
O
N
D

The results of the feeding analyses in North Arm and St. Philips have been organized in two ways: (1) within each station, for each regular sample, the mean stomach fullness, the mean intestinal fullness, the mean volume, and the percentage volume of each food group per sample have been determined, and (2) within each study site mature fish from all stations combined were divided by sex and grouped into intervals of time. For each of these groups the mean stomach fullness, the mean intestinal fullness, and the mean volume of food in the stomachs were determined. These groups of flounders correspond to those in the analysis of the body weight data, for which this grouping was established.

Winter flounders in North Arm had begun feeding by May 10/11 (Figures 17 and 18). Through May and June the females collected were feeding relatively heavily, whereas the males were not (Figures 19 and 20). From July to October flounders of both sexes in North Arm were feeding rather intensively. By November the food intake had decreased to a low level. This is indicated by all three feeding indices in both sexes and in the regular biweekly samples with the sexes combined. From December through early March when sampling ended the fish collected were not feeding, with one exception--a male collected in Station A on December 5.

In St. Philips winter flounders with food in their stomachs were first collected on May 6 in Station B (Figure 22). Through May they were feeding intensively (Figures 21 and 22), females perhaps at their greatest intensity of the year (Figures 24 and 25). Few males were collected in May to July so these were grouped together. Their mean stomach fullness and mean intestinal fullness values during this

FIGURE 17

North Arm, Station A: feeding indices of winter flounders collected on regular sampling dates. Sexes are combined. (a) mean stomach fullness, mean intestinal fullness, (b) mean volume.

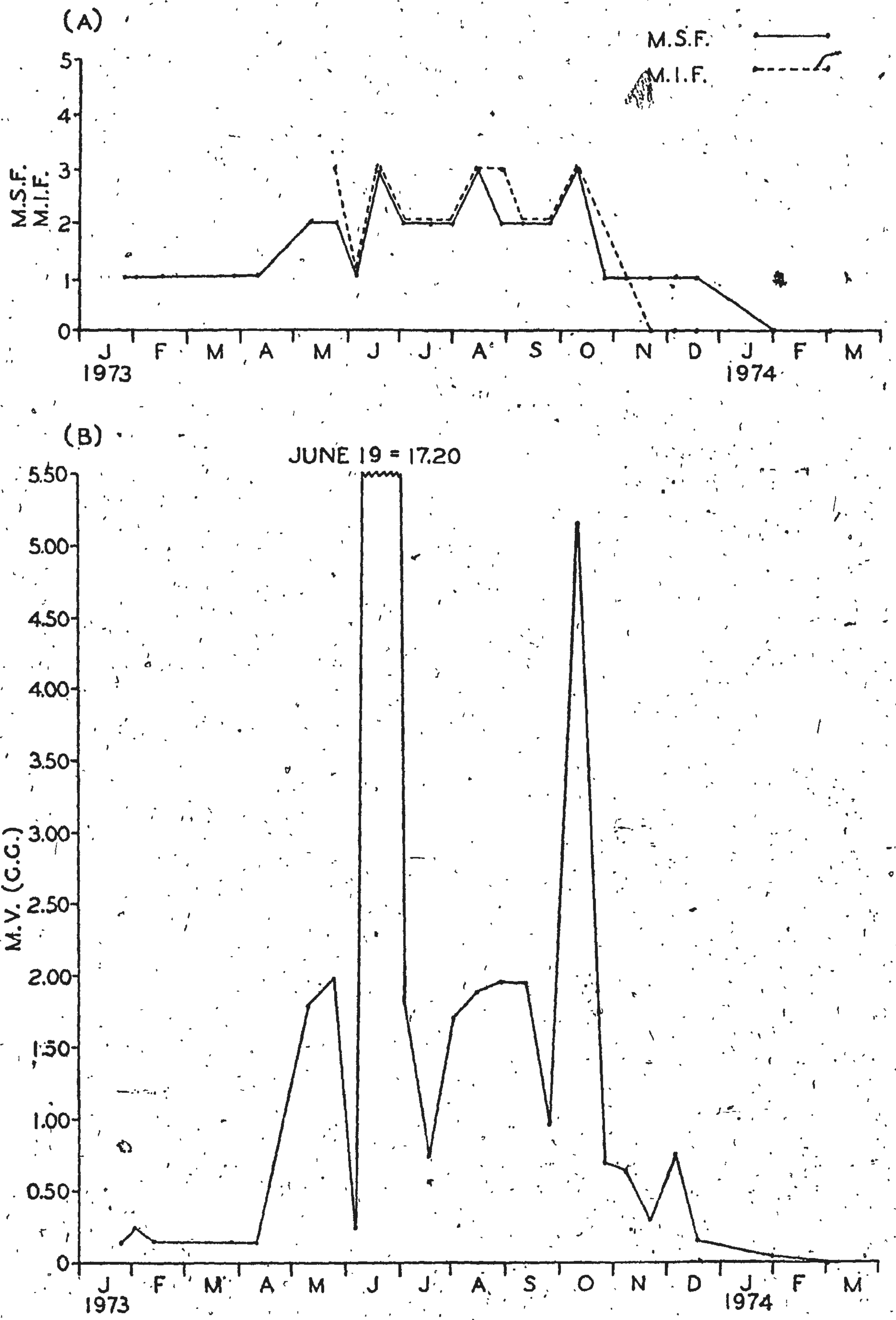
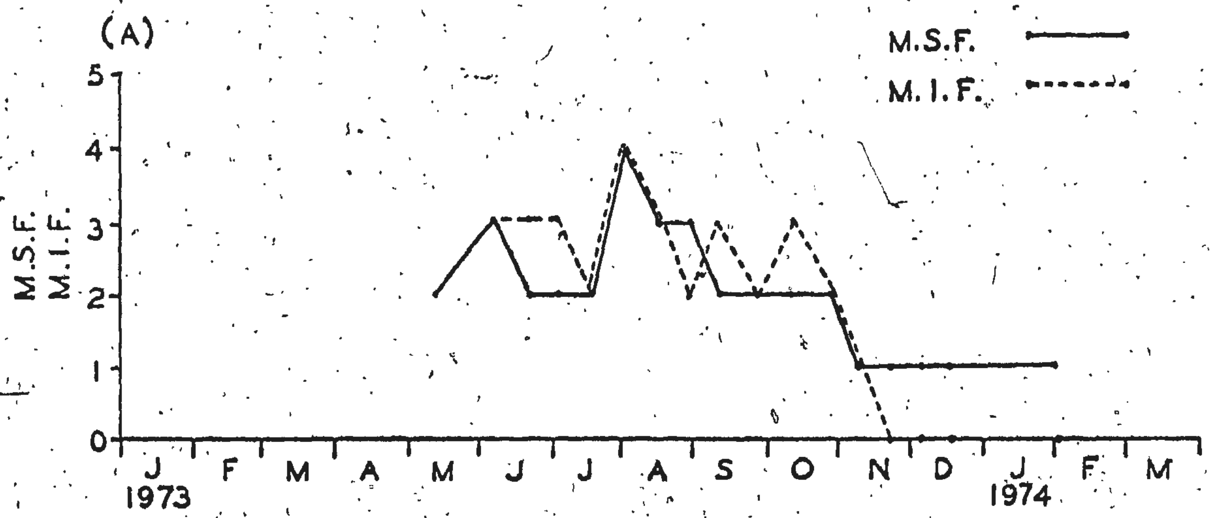

(A)
M.S.F.
M.I.F.
M.S.F.
M.I.F.
5
4
3
2
1
0
J
1973
F
M
A
M
J
J
A
S
O
N
D
J
1974
F
M
(B)
JUNE 19 = 17.20
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0
M.V. (C.C.)
J
1973
F
M
A
M
J
J
A
S
O
N
D
J
1974
F
M

FIGURE 18

North Arm, Station B: feeding indices of winter flounders collected on regular sampling dates. Sexes are combined. (a) mean stomach fullness, mean intestinal fullness, (b) mean volume.


(A)
M.S.F.
M.I.F.
M.S.F.
M.I.F.
5
4
3
2
1
0
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
1973
1974

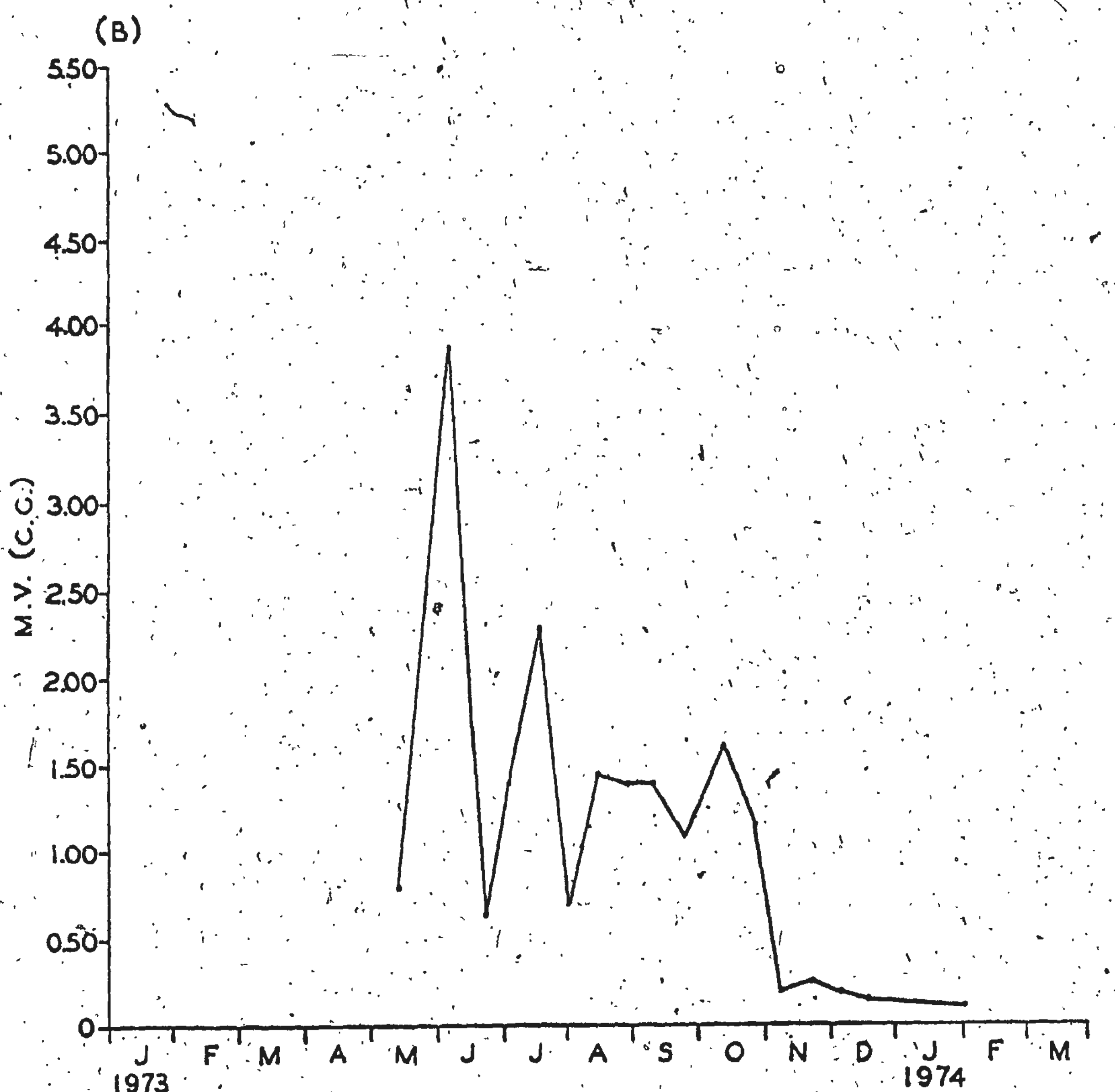

(B)
M.V. (C.C.)
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
1973
1974

FIGURE 19

North Arm (all stations combined): mean stomach fullness and mean intestinal fullness of each sex divided into intervals of time. (a) males, (b) females.

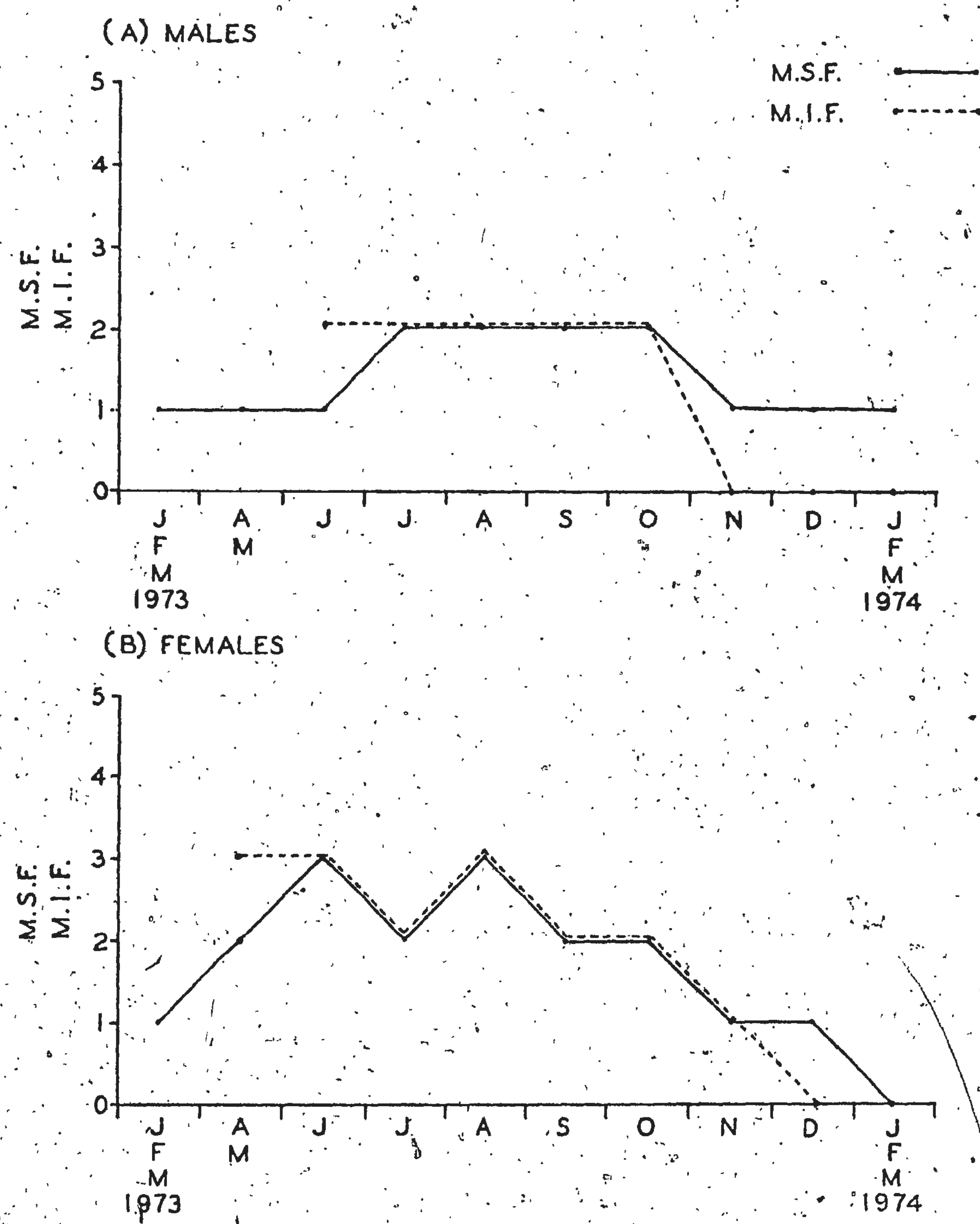

(A) MALES
M.S.F.
M.I.F.
5
4
3
2
1
0
J F M 1973
A M
J
J
A
S
O
N
D
J F M 1974
(B) FEMALES
M.S.F.
M.I.F.
5
4
3
2
1
0
J F M 1973
A M
J
J
A
S
O
N
D
J F M 1974

FIGURE 20

North Arm (all stations combined): mean volume of food of each sex divided into intervals of time. Vertical lines are ± 2 standard deviations, truncated at 0 and 12.00 cc.

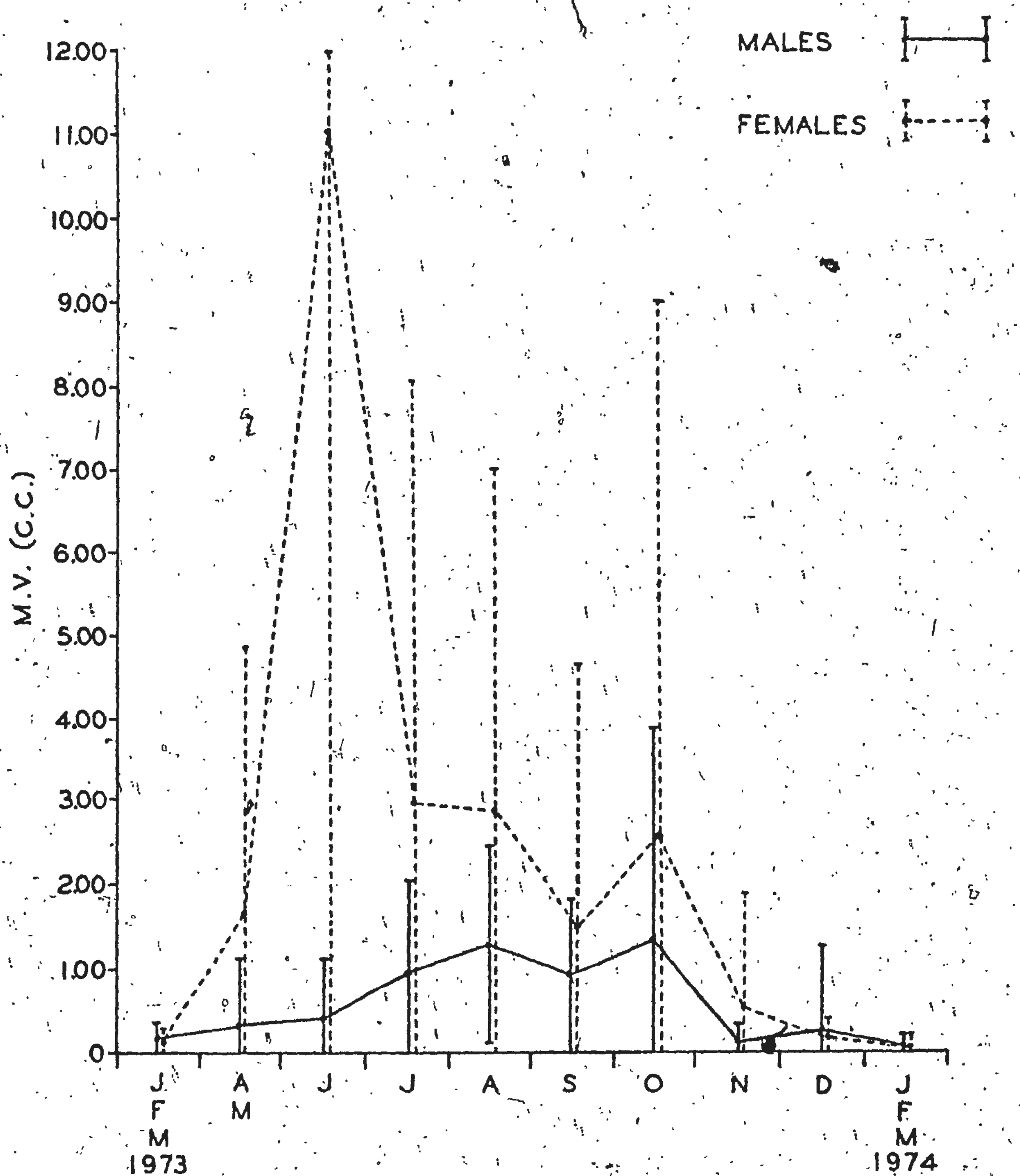
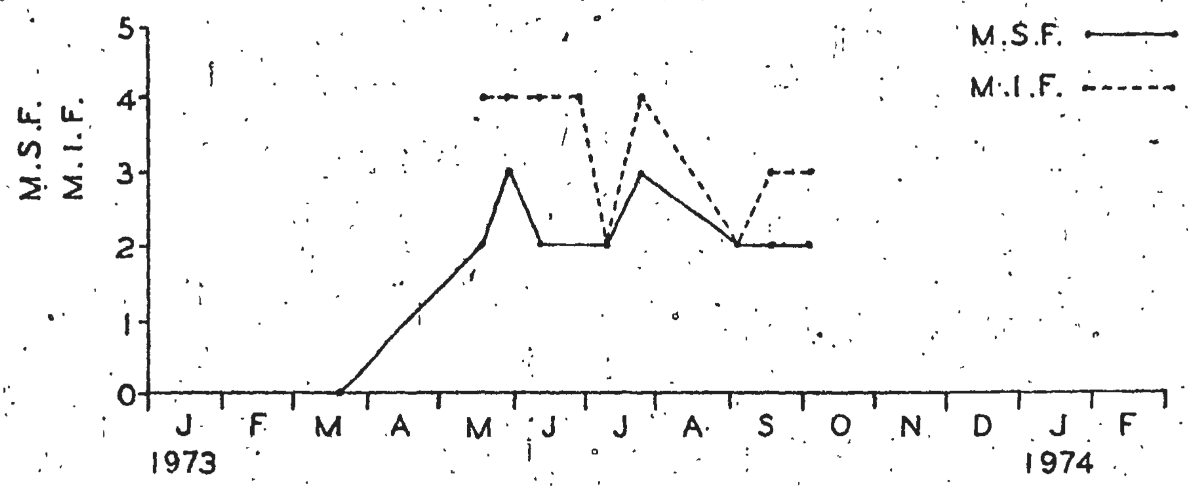

MALES
FEMALES
M.V. (C.C.)
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
J F M 1973
A M
J
J
A
S
O
N
D
J F M 1974

FIGURE 21

St. Philips, Station A: feeding indices of winter flounders collected on regular sampling dates. Sexes are combined. (a) mean stomach fullness, mean intestinal fullness, (b) mean volume.

(A)


M.S.F.
M.I.F.
M.S.F.
M.I.F.
0
1
2
3
4
5
J F M A M J J A S O N D J F
1973
1974

(B)

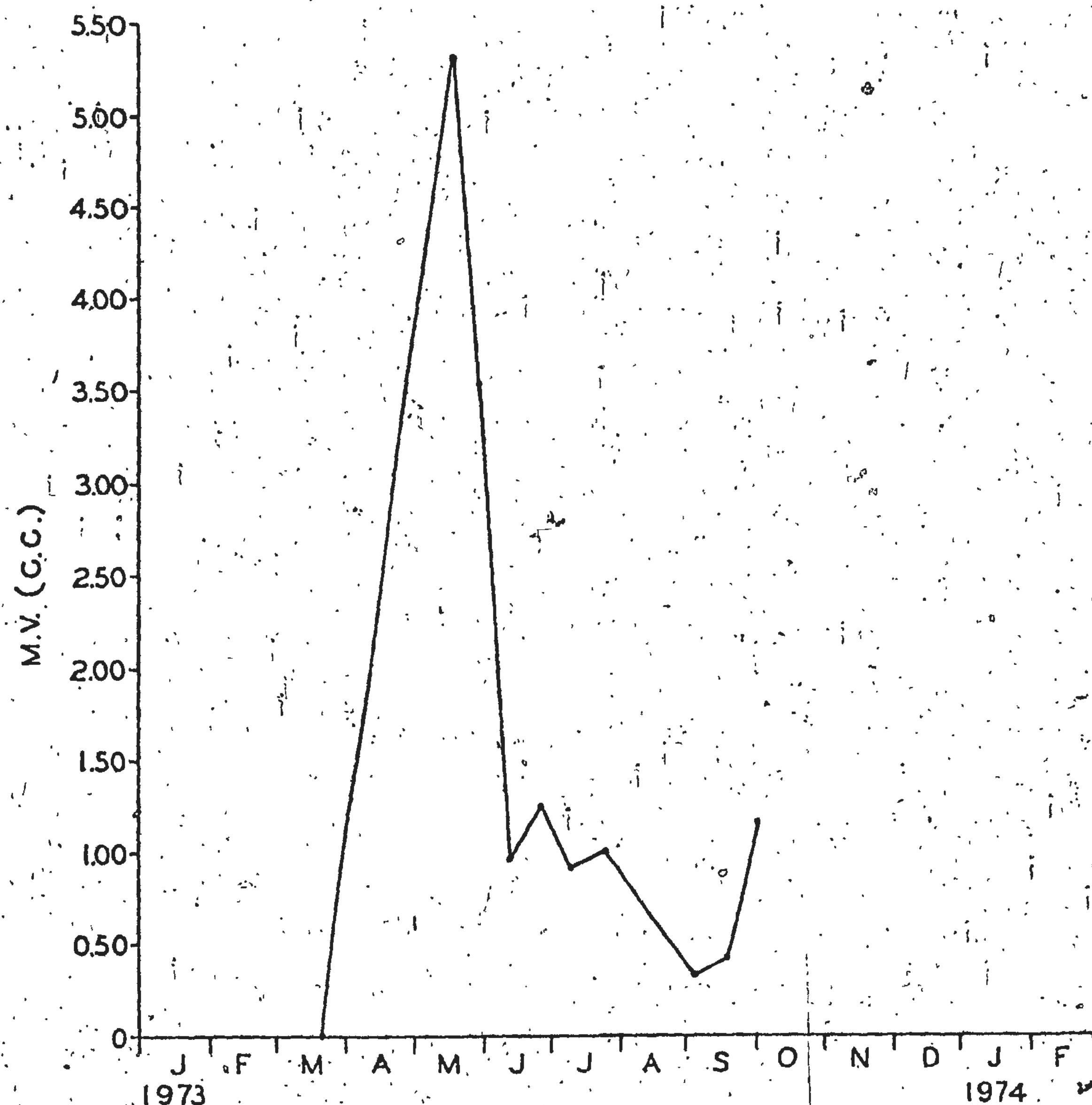
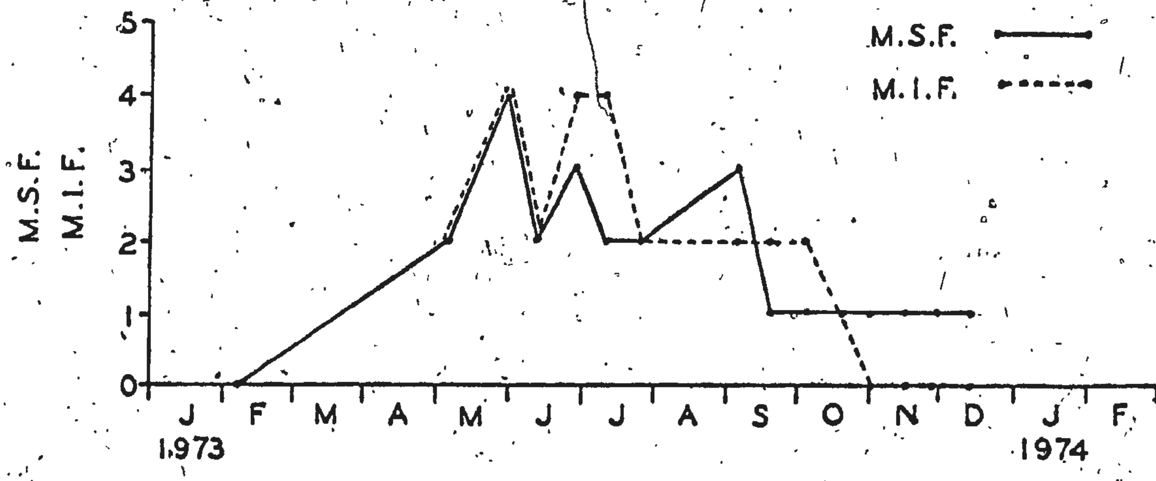

M.V. (C.C.)
0
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
J F M A M J J A S O N D J F
1973
1974

FIGURE 22

St. Philips, Station B: feeding indices of winter flounders collected on regular sampling dates. Sexes are combined. (a) mean stomach fullness, mean intestinal fullness, (b) mean volume.

(A)


M.S.F.
M.I.F.
M.S.F.
M.I.F.
5
4
3
2
1
0
J F M A M J J A S O N D J F
1973
1974

(B)

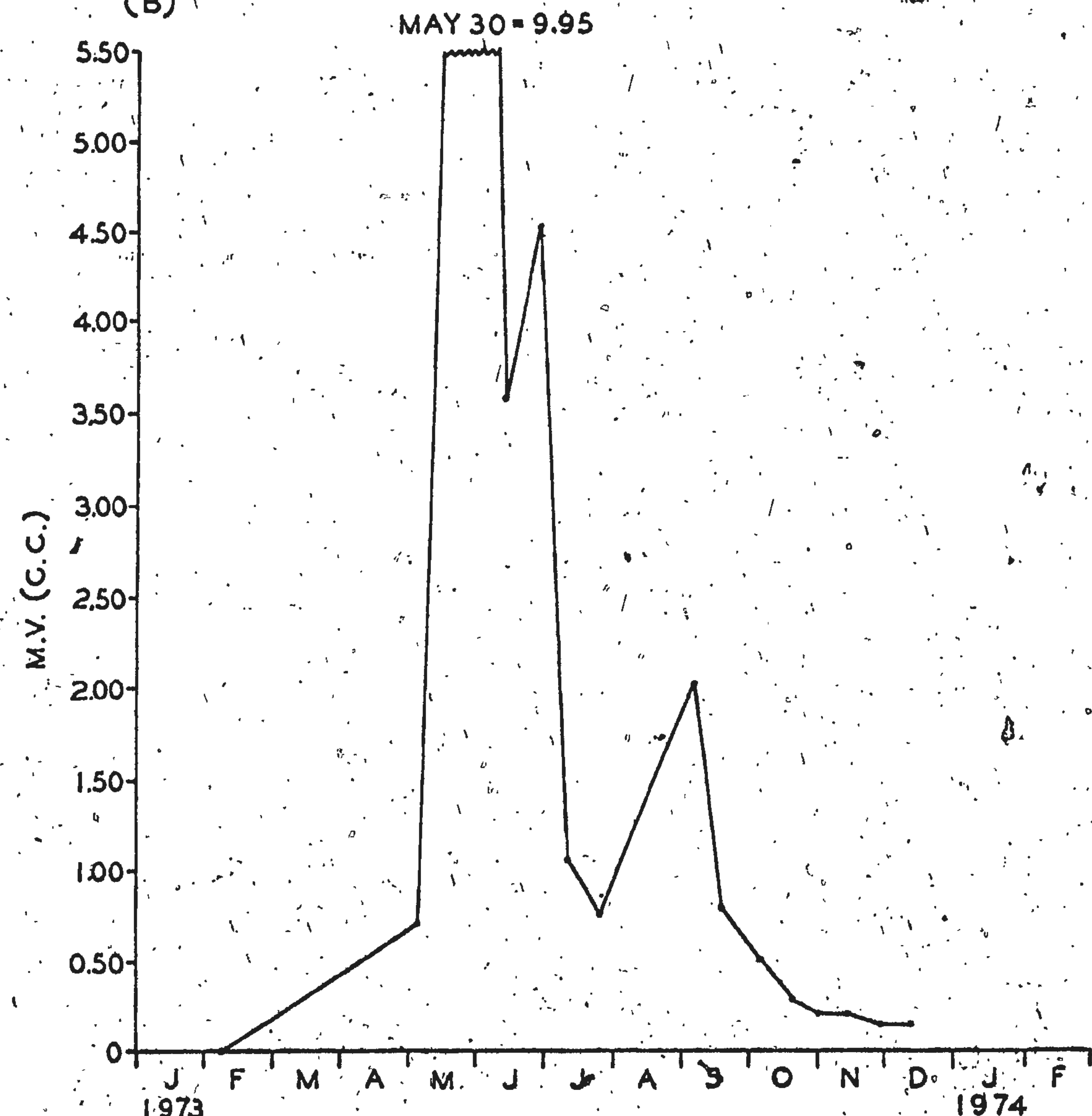

MAY 30 = 9.95
M.V. (C.C.)
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0
J F M A M J J A S O N D J F
1973
1974

FIGURE 23

St. Philips, Station C: feeding indices of winter flounders collected on regular sampling dates. Sexes are combined. (a) mean stomach fullness, mean intestinal fullness, (b) mean volume.

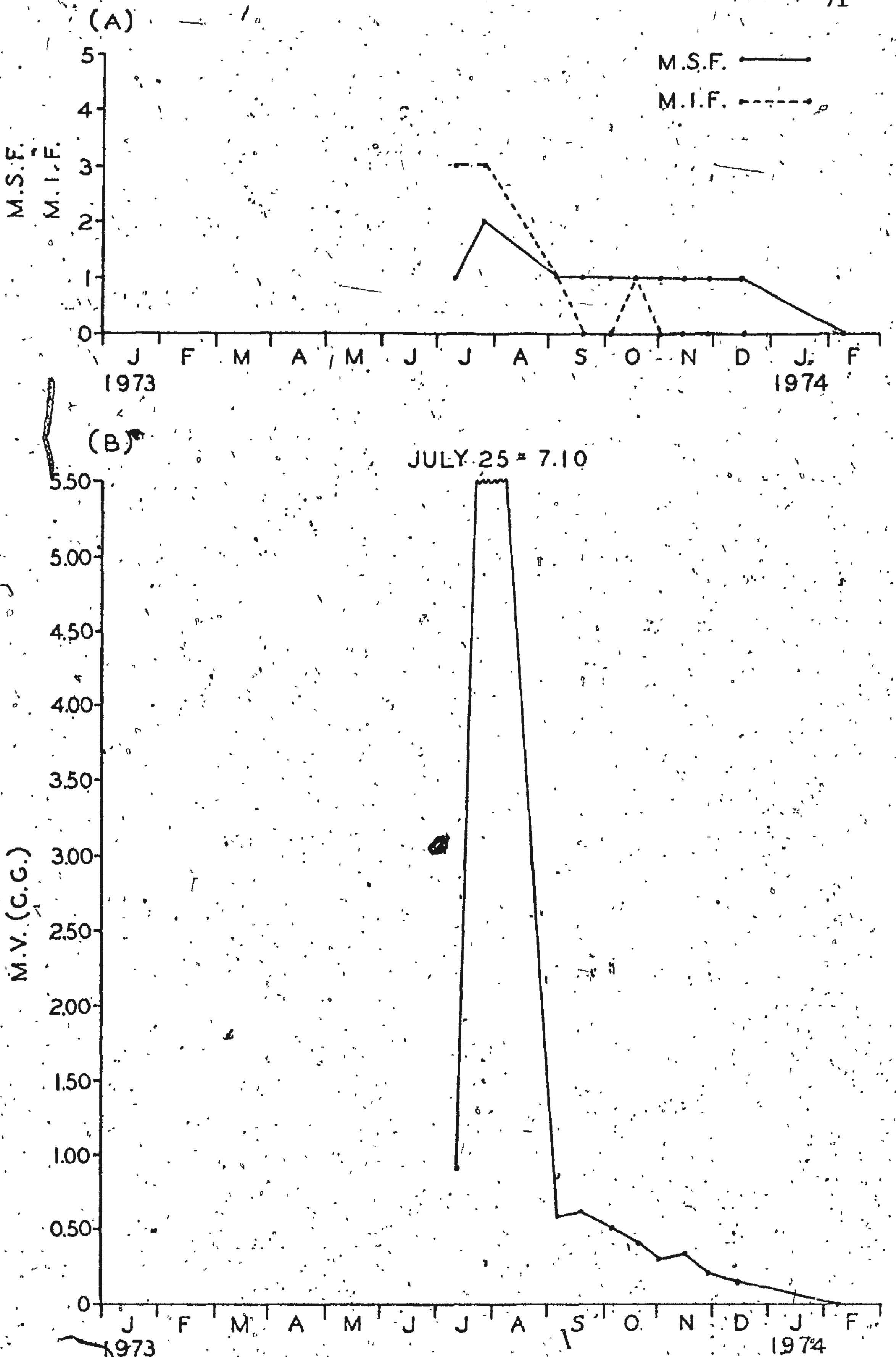

(A)
M.S.F.
M.I.F.
M.S.F. M.I.F.
0
1
2
3
4
5
J F M A M J J A S O N D J F
1973
1974
(B)
JULY 25 = 7.10
M.V. (C.G.)
0
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
J F M A M J J A S O N D J F
1973
1974

FIGURE 24

St. Philips (all stations combined): mean stomach fullness and mean intestinal fullness of each sex divided into intervals of time. (a) males (May, June, and July are combined), (b) females.

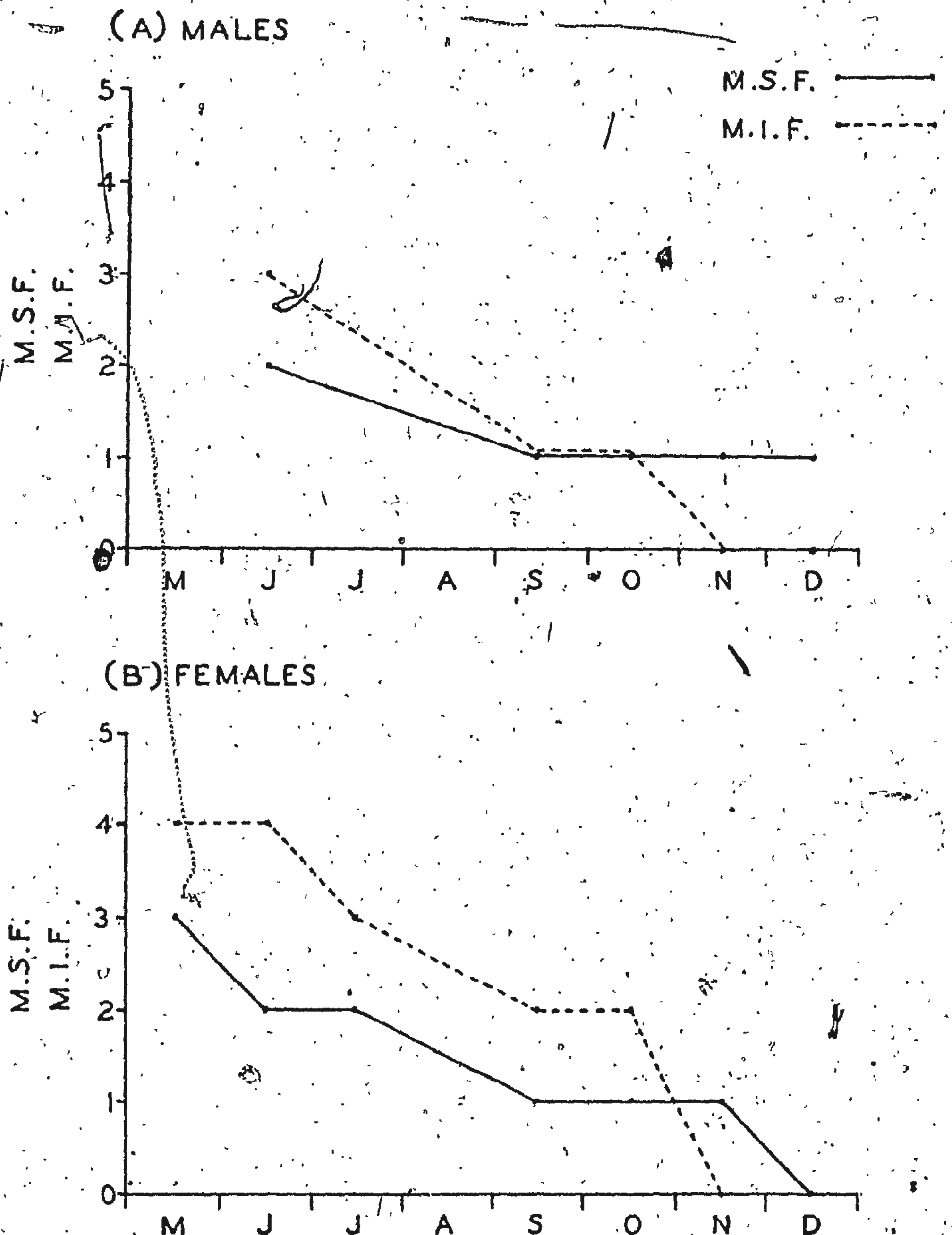
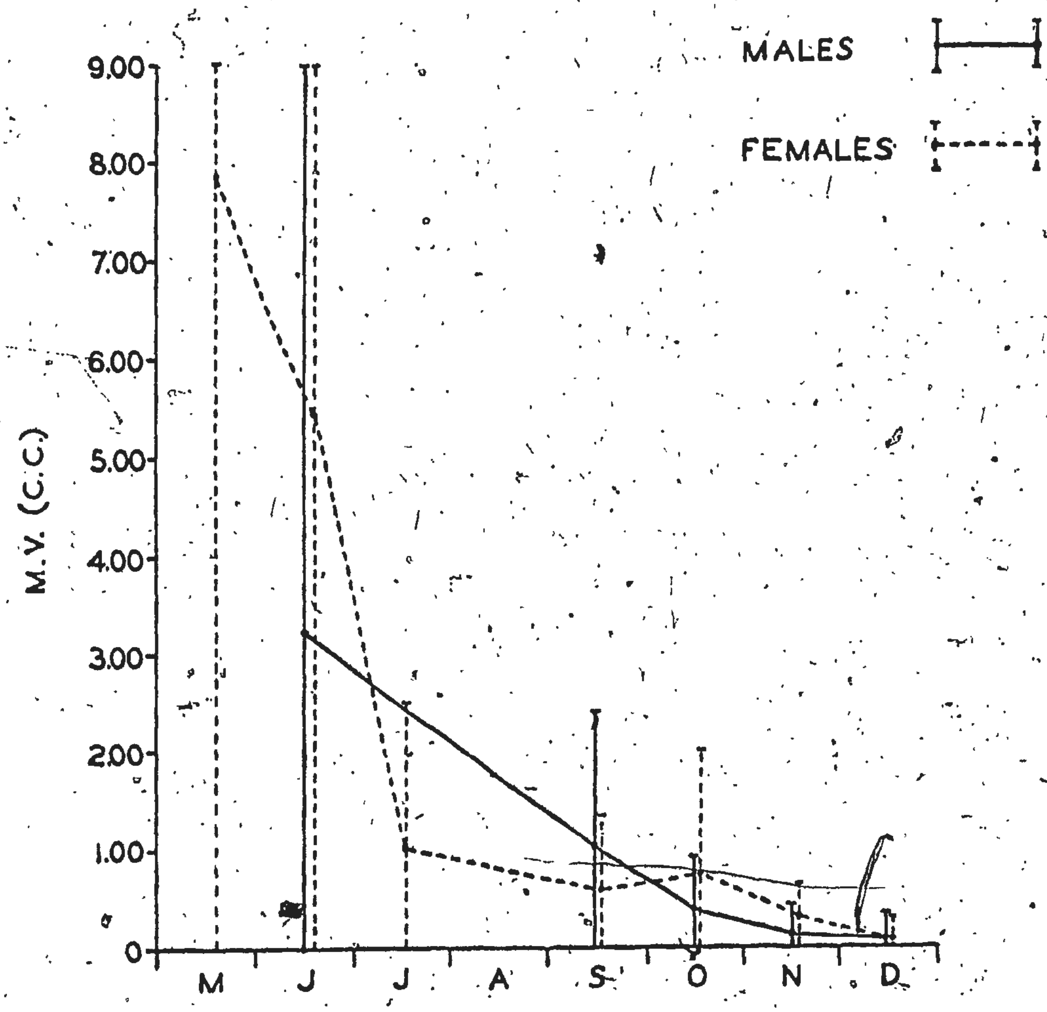

(A) MALES
M.S.F.
M.I.F.
0
1
2
3
4
5
M
J
J
A
S
O
N
D
(B) FEMALES
M.S.F.
M.I.F.
0
1
2
3
4
5
M
J
J
A
S
O
N
D

FIGURE 25

St. Philips (all stations combined): mean volume of food of each sex divided into intervals of time. May, June, and July are combined in the males. Vertical lines are ± 2 standard deviations, truncated at 0 and 9.00 cc.


MALES
FEMALES
M.V. (C.C.)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
M
J
J
A
S
O
N
D

period indicate that they were feeding at a maximum level for the year (Figure 24). Feeding in the females remained high through June and July. Winter flounders were absent from St. Philips during August, thus none were collected. By September their feeding intensity had begun to decline from the level of June and July, especially in Station C (Figure 23). Fish from Station A were still feeding relatively heavily in early October (Figure 21), unlike Stations B and C. Feeding by St. Philips flounders ceased in early November.

The percentage volume per sample of each group of food organisms of winter flounders [illegible] each station are given in Appendices G-K. The principal food organisms of flounders taken from North Arm appear to have been, in order of importance, polychaetes and algae in Station A and algae and polychaetes in Station B. Sand tube polychaetes acheived importance mainly at the end of the feeding season in both stations. Of lesser importance in Station A were pelecypods and amphipods, and in Station B oligochaetes, pelecypods, sea anemones (Actiniaria) and cumaceans. Four of the seven flounders collected in Station A on June 19 had been gorging on dead capelin, *Mallotus villosus* (Müller), thus capelin remains comprised 93 percent of the total volume of food of that sample. Fish remains were not included in the diet of flounders taken from Station B. Of the stomach contents of the June 5 and 19 samples from Station A, 2 percent of the former sample consisted of what appeared to be winter flounder eggs and of the latter sample, 1 percent was probably winter flounder eggs and 5 percent was capelin eggs. Fish eggs appeared in the diet of flounders from Station B on July 3 only. They were identified as capelin eggs from one fish of the sample; eggs from the stomachs of two other fish were too well digested to be identified. The eggs of these three fish, mixed with unidentifiable organic matter and debris, formed 57 percent of the total food volume of the sample.

In St. Philips the chief food organisms of winter flounders taken from Station A were polychaetes and chitons (Polyplacophora). Also important were sea urchins (*Strongylocentrotus droebachienses*), algae, sea anemones, limpets (Gastropods), and brittle stars (Ophiuroidea). Of the flounders taken from Station B, algae was the principal recognizable food. Sea anemones were important on two dates, June 27 and September 6. Of lesser importance in Station B were polychaetes, pelecypods, amphipods, and sea urchins. In the June 11 sample from Station B fish remains comprised 91 percent of the total food volume. Only one of the four fish in the sample had been feeding on fish remains. These remains included large eyes which indicate that they were not capelin. In the July 25 sample from Station B one of three flounders collected had been feeding on capelin eggs. Mixed together with unidentifiable organic matter and debris, these components formed 91 percent of the total food volume of the sample. At least 40 percent of the total volume (a visual estimate) was eggs. One of the four flounders taken from Station C on July 25 had also been eating capelin eggs, which together with unidentifiable organic matter and debris comprised 98 percent of the total food volume of the sample. Approximately 90 percent of the total volume (again a visual estimate) was eggs. The only other food organism of any significance found in flounders from Station C was the sea urchin, which occupied 26 percent and 2 percent of the total food volume on July 11 and September 6 respectively.

Seven flounders collected on August 10 from St. Thomas Cove (Figure 1) had been feeding exclusively on capelin eggs.

C. Seasonal Movements

Table 4 gives the tagging dates, the number of fish tagged on each date, and the tag returns made in each station. It is evident that nearly all tag returns were made in the stations in which the observed flounders were tagged. The exceptions were three returns made in St. Philips Station C of fish tagged in Station B, and these were all made at the end of the Station C transect which is near Station B.

The results of the counts on each sampling date are given in Figures 26 and 27 and Appendices L and M, and are expressed as the mean number of winter flounders per 300 square meter count. Because it was required in some of the statistical analyses, the portable quadrat counts were doubled to give mean fish per 300 square meters, and counts in North Arm Station B after April 11 were transformed from mean fish per 420 square meters to mean fish per 300 square meters.

For each station Table 5 gives the F value and respective probability level for the analysis of variance of flounder abundance among sampling dates. Significant differences in abundance with time, from Duncan's new multiple range test, are given in Figure 28. Though the F value for St. Philips Station A was insignificant (Table 5), the

TABLE 4

Information for each station on tagging dates, the number of winter flounders tagged on each date, and tag returns made

Station	Tagging date	Number of fish tagged	Tag returns: Date	Tag returns: Number of Returns	Tag returns: Station and date tagged
North Arm Station A	April 15	48	June 7	1	Sta. A April 15
	May 27	34	June 25	2	Sta. A May 27
	June 7	16	July 31	1	Sta. A May 27
			Aug. 26	1	Sta. A May 27
			Aug. 28*	2	Sta. A
			Sept. 11*	1	Sta. A
			Nov. 21	1	Sta. A
			Dec. 5	1	Sta. A May 27
			April 8/74**	1	Sta. A April 15/73
North Arm Station B	June 9	38	Aug. 15	1	Sta. B June 15
	June 15	13	Sept. 21	1	Sta. B June 15
	Sept. 21	14	Oct. 25*	1	Sta. B
			Dec. 18	1	Sta. B Sept. 21
St. Philips Station B	July 15	24	July 22	1	Sta. B July 15
	July 22	25	Sept. 6	1	Sta. B July 15
	Sept. 28	38	Dec. 13	2	Sta. B Sept. 28
St. Philips Station C	Oct. 5	35	Oct. 18	1	Sta. B July 22
			Nov. 16*	1	Sta. B
			Dec. 14	1	Sta. B Sept. 28

*Tag number was not obtained, therefore tagging date is unknown.
**Collected by diving staff of the Marine Sciences Research Laboratory.

FIGURE 26

North Arm: for each station the mean number of winter flounders per 300 square meter count on each sampling date (from Appendix L). S (= significant at the 0.05 protection level) shows significant changes in abundance within stations on adjacent sampling dates.

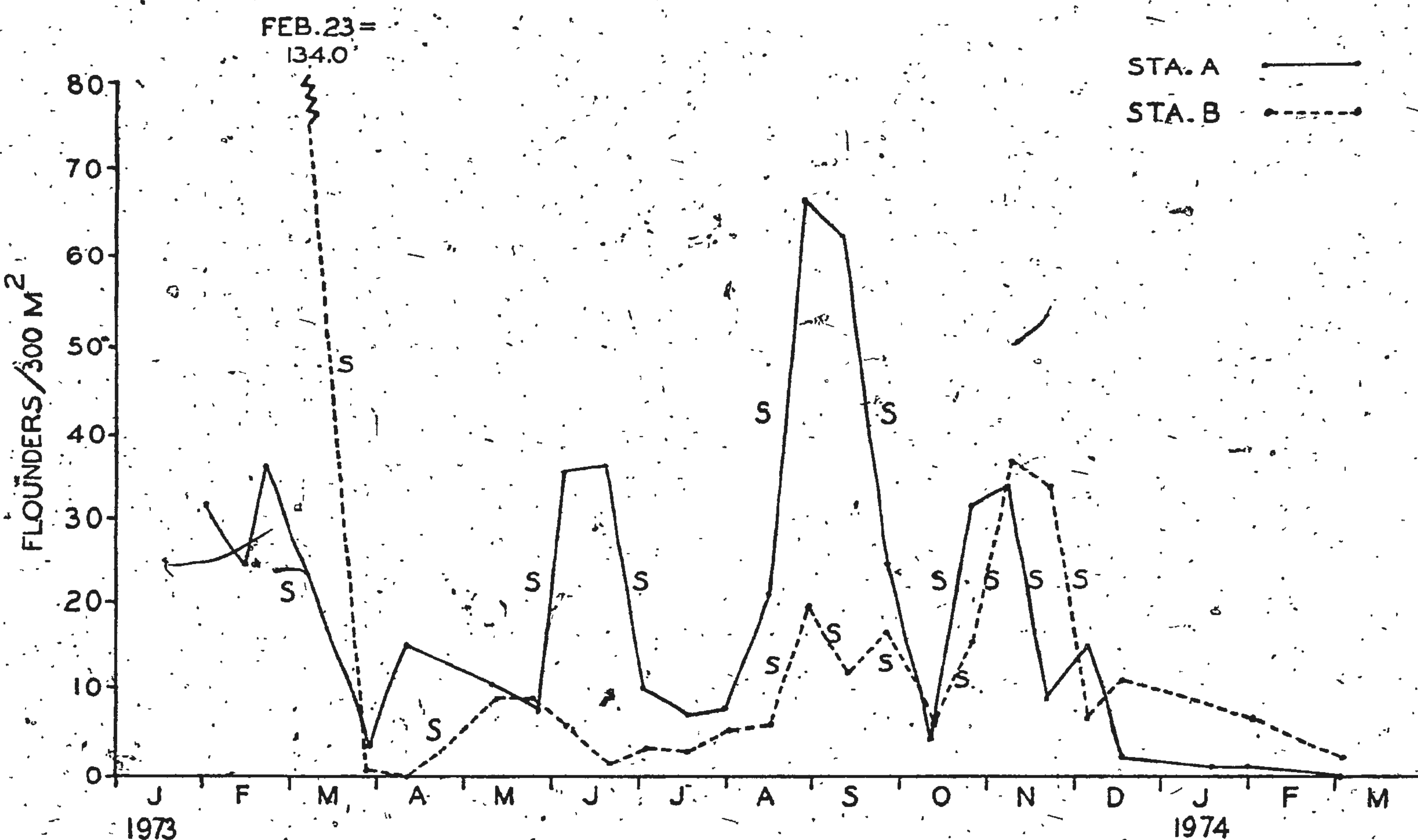

FEB.23=
134.0
STA. A
STA. B
FLOUNDERS/300 M²
80
70
60
50
40
30
20
10
0
J F M A M J J A S O N D J F M
1973
1974
S

FIGURE 27

St. Philips: for each station the mean number of flounders per 300 square meter count on each sampling date (from Appendix M). S (= significant at the 0.05 protection level) shows significant changes in abundance within stations on adjacent sampling dates.

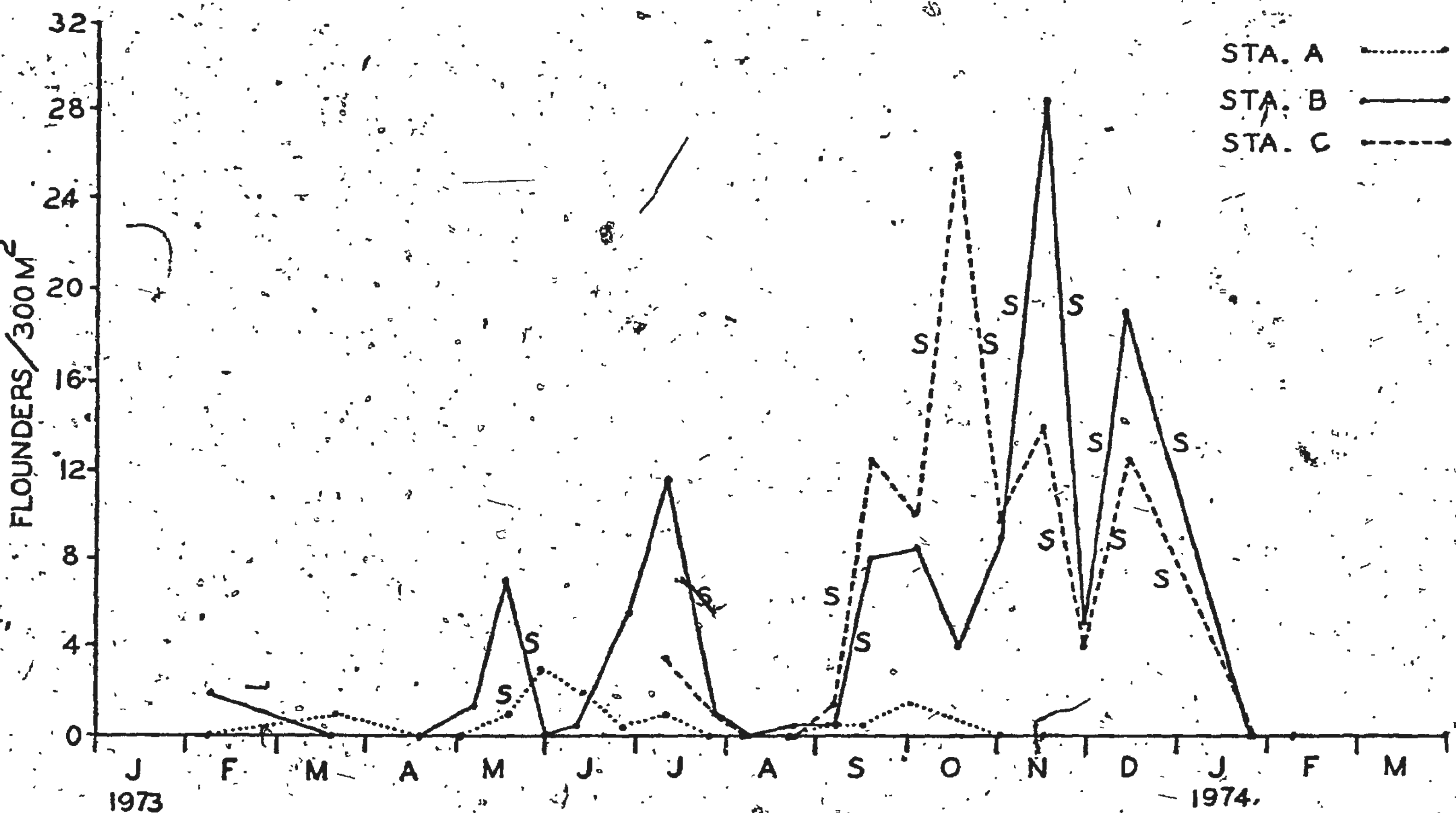

STA. A
STA. B
STA. C
FLOUNDERS/300 M²
32
28
24
20
16
12
8
4
0
S
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
1973
1974

FIGURE 28

For each station an analysis of the abundance data among sampling dates using Duncan's new multiple range test. Dates are ranked according to decreasing number of mean fish per count. Any two means underscored by the same line are not significantly different (Steel and Torrie, 1960).

(a) North Arm, Station A		(b) North Arm, Station B	
Date	Mean fish/count	Date	Mean fish/count
Aug. 28,	66.5	Feb. 23, 1973	188.0
Sept. 11,	62.5	Nov. 8,	51.5
Feb. 22, 1973	36.0	Nov. 22,	46.5
June 19,	36.0	Aug. 29,	27.5
June 5,	35.0	Sept. 26,	23.5
Nov. 7,	33.0	Oct. 25,	22.5
Feb. 2, 1973	32.0	Sept. 12,	17.5
Oct. 24,	31.5	Dec. 18,	15.0
Feb. 14, 1973	24.0	May 11,	12.0
Sept. 25,	24.0	May 23,	12.0
Aug. 14,	20.5	Feb. 1, 1974	9.5
Apr. 10,	15.0	June 6,	9.0
Dec. 5,	15.0	Dec. 6,	9.0
May 10,	10.0	Oct. 11,	8.5
July 3,	9.5	Aug. 1,	8.0
Nov. 21,	8.5	Aug. 15,	8.0
May 24,	7.5	July 3,	4.5
July 31,	7.5	July 18,	4.5
July 18,	7.0	Mar. 2, 1974	3.5
Oct. 10,	4.5	June 20,	3.0
Mar. 27, 1973	4.0	Mar. 26, 1973	1.5
Dec. 17,	2.5	Apr. 11,	0
Jan. 19, 1974	1.5		
Jan. 30, 1974	1.5		
Mar. 1, 1974	0		

(c) St. Philips, Station A		(d) St. Philips, Station B	
Date	Mean fish/count	Date	Mean fish/count
May 29,	3.0	Nov. 16,	28.5
June 12,	2.0	Dec. 13,	19.0
Oct. 3,	1.5	July 11,	11.5
Mar. 20, 1973	1.0	Nov. 1,	9.0
May 18,	1.0	Oct. 4,	8.5
July 10,	1.0	Sept. 19,	8.0
June 26,	0.5	May 16,	7.0
Sept. 4,	0.5	June 27,	5.5
Sept. 18,	0.5	Nov. 29,	5.0
Feb. 7, 1973	0	Oct. 18,	4.0
Apr. 18,	0	Feb. 7, 1973	2.0
May 1,	0	May 6,	1.5
July 24,	0	July 25,	1.0
Aug. 7,	0	June 11,	0.5
Aug. 21,	0	Aug. 22,	0.5
Oct. 31,	0	Sept. 6,	0.5
Nov. 15,	0	Mar. 19, 1973	0
		Apr. 18,	0
		May. 30,	0
		Aug. 8,	0
		Jan. 24, 1974	0
		Feb. 8, 1974	0

(e) St. Philips, Station C	
Date	Mean fish/count
Oct. 18,	26.0
Nov. 16,	14.0
Sept. 19,	12.5
Dec. 14,	12.5
Oct. 4,	10.0
Nov. 1,	4.5
Nov. 29,	4.0
July 11,	3.5
Sept. 6,	1.5
July 25,	0.5
Aug. 8,	0
Aug. 22,	0
Jan. 25, 1974	0
Feb. 8, 1974	0

TABLE 5

F values and respective probability levels for the analysis of variance of mean fish per count among sampling dates

Station	F	Probability Level
North Arm, Station A	9.65	< 0.005
North Arm, Station B	96.49	< 0.005
St. Philips, Station A	2.10	0.05 < P < 0.10
St. Philips, Station B	12.81	< 0.005
St. Philips, Station C	19.99	< 0.005

TABLE 6

Results of χ^2 tests for homogeneity of abundance data for North Arm Station A versus Station B and St. Philips Station B versus Station C. Probability levels marked with asterisks are highly significant

Stations	χ^2	Degrees of Freedom	Probability Level
North Arm, Station A versus Station B	224.917	21	0.999**
St. Philips, Station B versus Station C	28.918	10	0.999**

abundance data of that station was analyzed by Duncan's test since the procedure may be used regardless of the significance of F (Steel and Torrie, 1960). In Figures 26 and 27 the significant changes in abundance on adjacent sampling dates in each station are marked with an "S".

The results of the X^2 tests for homogeneity of abundance data for North Arm Station A versus Station B and for St. Philips Station B versus Station C are given in Table 6.

That seasonal movements of winter flounders occurred in North Arm and St. Philips is evident from the significant changes in abundance which occurred with time in each station (Table 5, Figure 28). But the highly significant X^2 values obtained (Table 6) indicate that movements were not the same in North Arm Stations A and B, or in St. Philips Stations B and C. This interaction of the variables time and station is apparent in North Arm in February, June and August/September (Figure 26), and in St. Philips in mid-October and mid-November (Figure 27).

1. North Arm

When the survey began in February, 1973 winter flounder numbers were relatively high in Station A and very high in Station B (Figure 26). The February 23 count in Station B was made at the greatest depth of that station (Figure 2), and may have involved a single large concentration of fish. If this was so then the abundance value obtained would not have been representative of abundance throughout Station B. By late March flounder abundance in both stations decreased significantly to a very low level. Since the two counts of March 26 in Station

B were made in a somewhat different location than that of February 23, it is possible that the large concentration of February 23 remained in Station B through March.

Observations through April indicated that winter flounders were concentrating in Station A. Very few were observed in Station B on April 11 when a large bottom area was surveyed (including the greatest depth where numbers were high on February 23). Abundance in Station A increased insignificantly from March 27 to April 10, and flounders were abundant in the center region of Station A on the tagging dive of April 15. The locations of these three dives in Station A overlapped. Thus abundance appears to have been increasing in April in Station A. But between April and May flounders once again moved out of Station A. The decrease in abundance was not statistically significant, but had a count been made on April 15 when flounders were plentiful the decrease would probably have been significant. During this period numbers in Station B rose slightly but significantly, which may have been due to movement of fish from Station A to Station B and beyond. Abundance in both stations remained steady through the rest of May.

In early June a significant number of winter flounders moved rapidly into Station A; numbers decreased insignificantly in Station B. A tagged flounder was observed in Station A on June 7, tagged there April 15. This was the first tag return since the growing April concentration moved out in mid-April, and may indicate that it was this same stock which returned in June. Flounders were aggregated near shore in the shallowest depths of both stations. They remained there through June as abundance continued at relatively steady levels. Winter flounders were also abundant at a position on the southern shore at the mouth of North Arm (Figure 2) on June 22, at depths of 6-7.5 m. Few fish were observed in Station D on June 22 (Appendix L). Thus it appears that the flounders of North Arm were concentrating along the shoreline in June, particularly at the head and mouth of the inlet.

In the second half of June the majority of winter flounders moved out of Station A. They did not concentrate in Station B since abundance there remained very low. Therefore they must have moved through Station B to a new location, possibly in deeper water. The few flounders that remained in Stations A and B through July formed loose aggregations in the shallower water near shore. On July 31 a tagged fish was observed in Station A, tagged there on May 27. This was the first tag return since the emigration in latter June, and may have been one of the first arrivals of the August influx into Station A.

In the first half of August winter flounders began moving into Station A, though the increase in abundance was not significant. There was no change in flounder numbers in Station B. Abundance in Station D was greater than in Station B but less than in Station A. Flounders were very rare in the shallow water at the southern shore of the mouth of North Arm, unlike the other regions. A tag return in Station B on August 15 was the first of forty-nine fish tagged there in June to be observed and may have been among those migrating into the shallows of North Arm.

In the second half of August there was a large movement of flounders into North Arm. The increase in abundance was significant in both stations, but there were many more fish in Station A than in Station B. Flounder density in Station A was at a maximum for the year. There was little change in abundance in September in Station A; a small but significant decrease occurred in Station B and may have been due to continued movement into Station A. More tag returns occurred during this peak in numbers in Station A than at any other time of the year (Table 4). There were also two tag returns in Station B in that period of fish tagged there in June. Thus it appears that the stock of flounders which moved into North Arm in August included fish which had been present there earlier in the year. This peak in Station A was significantly greater than the peak which occurred in June (Figure 28).

In September flounder abundance in Station A decreased sharply. There was a small and insignificant increase in numbers in Station B, indicating that most of the flounders which were in Station A moved beyond Station B.

On October 10/11 the numbers of flounders in both stations were low. By October 24/25 flounder abundance in both stations had increased significantly to approximately the same levels as those just prior to October 10/11. It is probable that the fish moved to somewhat deeper water beyond Station B in the interim, for a reason to be discussed later, and then returned to the shallow water of Station B and especially Station A. By early November abundance in Station B had risen significantly to the level of Station A. This suggests further movement back into shallow water. These flounders in Station B were concentrated mainly in the deepest region of the station, just as they were on February 23, 1973. Most of the fish in Station A were also found in the deepest water. This depth distribution continued until the end of the survey.

During November flounder abundance decreased significantly in Station A, while numbers in Station B remained unchanged, indicating a movement of fish out of the shallowest depths of North Arm. By early December the majority of flounders had also moved out of Station B. Through December abundance in Station A fell to the lowest level to that date and remained very low until counting was terminated in early March. Abundance in Station B decreased more gradually but significantly from December to a very low level in early March.

From mid-December to early March the abundance of winter flounders in Station B was consistently greater than in Station A. A similar distribution was apparent the previous February although there were many more fish in Stations A and B that winter.

On April 8, 1974 the diving staff of the Marine Sciences Research Laboratory collected winter flounders from North Arm for laboratory use. They surveyed the region between Stations A and B and observed very few flounders. But in a location near the southern shore bordering on Station A they found a concentration of "hundreds of flounders" in approximately 6 m of water. This concentration was definitely not there on March 1. They recovered a tagged flounder, tagged in Station A on April 15, 1973.

To summarize, relatively large numbers of winter flounders were present in the shallow waters of North Arm in February, April, June, late August/September, and late October to November. Numbers were much lower in March, May, July, mid-October, and December to March when counting ended.

2. St. Philips

Winter flounders were absent from St. Philips during February, March, and April of 1973 (Figure 27). In May some fish moved into the area. Abundance reached a small but significant peak (Figure 28) in Station B in mid-May, then decreased as numbers increased slightly but significantly in Station A, and also increased inshore of Station B in late May and early June. Thus a movement into the shallowest waters was indicated, but the numbers of fish involved was small. A dive in Station D on June 1 revealed no flounders, indicating perhaps that no more were entering the St. Philips region at that time.

The numbers of winter flounders in Station A remained very low through June and July. Numbers in Station B increased significantly to a small peak in mid-July. This peak was greater than that of mid-May, though the difference was insignificant. Numbers in Station C in mid-July were less than in Station B and greater than in Station A, though the confidence limits of the abundance figures overlap (Appendix M). Most of the fish observed at St. Philips in mid-July were located on a sandy bottom (Figure 5) in the shallower parts of Stations B and C, which are close together (Figure 3).

Through the second half of July flounder abundance decreased in the St. Philips area to a low level. The decrease in Station B was significant. By early August nearly all flounders had moved out of the St. Philips region, and they remained absent throughout the month. A dive in Station D on August 24 indicated that winter flounders were also very rare there. However, approximately one and one half miles down the coast at St. Thomas Cove, a shallow indentation in an exposed coastline (Figure 1) with a habitat very similar to St. Philips, a dive on August 10 revealed a very large and dense concentration of winter flounders numbering probably in the thousands. They were concentrated chiefly between 7.5 and 12 meters. Whether these fish immigrated from deeper water offshore or gathered from adjacent inshore regions such as St. Philips is unknown.

In the fall and early winter there was a greater abundance of winter flounders at St. Philips than at any other time of the year. Tag returns in Station B on September 6 and in Station C on October 18 of fish tagged in Station B in July (Table 4) show that this stock included flounders which were present earlier in the year. Immigration began in early September when more flounders were observed in all stations than were seen throughout August (this is not well indicated in the abundance data). The greatest abundance at that time was noted in the deeper water of Station D where flounders were found from approximately 20-23 m on a sandy bottom. None were observed from 24-29 m on a rocky bottom. By mid-September abundance had increased significantly in shallower Stations B and C, and to a similar level. Whether these flounders migrated from deeper water offshore or from nearby inshore regions such as St. Thomas Cove, is unknown. Through the rest of September flounder numbers in St. Philips remained relatively constant.

During the first half of October flounder abundance increased significantly in Station C and decreased insignificantly in Station B, so that numbers in Station C were much greater than in Station B. By November 1 the fish had returned to their distribution of early October. Abundance in both Stations B and C was restored to the same level as early October, and was similar in both stations. Winter flounders were absent in Station A from mid-October to mid-November when counting there was terminated.

During the first half of November flounder abundance increased significantly in Station B and insignificantly in Station C, so that numbers in Station B were greatest. In late November there was a sharp and significant decrease in abundance in both Stations B and C to a rather low level, suggesting that the flounders had rapidly vacated the St. Philips region. A dive on November 30 in Station D indicated that the stock had not moved into that area; so their new location remains unknown. But the stock returned by mid-December, with a significant increase in abundance occurring in both stations. That this was the same stock is indicated by tag returns in Stations B and C in December of fish tagged in Station B on September 28. Abundance in Station B in mid-December, when the stock returned, was significantly lower than in mid-November (Figure 28). This may be because in December the flounders were dispersed evenly throughout Station B, and were not aggregated in the shallow sandy region nearer to shore as on all previous dates. This change in distribution could result in somewhat lower counts. Abundance levels in Station C in mid-November and mid-December were similar, and on both dates, as always, the flounders were aggregated mainly at the shallower end of the transect.

The stock of winter flounders which was present at St. Philips in the fall and early winter had moved elsewhere by January, 1974. In early February, when counting ended at St. Philips, the flounders were still absent.

To summarize, winter flounders were present in the shallow waters of St. Philips is small numbers from May to mid-July and in larger numbers from mid-September to at least mid-December. Flounders were largely absent during February to April, August, and late January to early February, when counting ended.

IV. DISCUSSION

Qualitative information was obtained on seasonal changes in the abundance of winter flounders in three locations on the Avalon Peninsula of Newfoundland. Seasonal movements of the winter flounder in regions to the southwest of Newfoundland have been described in the literature. These movements will be briefly reviewed by regions from north to south. The seasonal movements of winter flounders in North Arm and St. Philips and their apparent causes will then be described. A general scheme of seasonal movements of winter flounders throughout their range and the causes of these movements will be suggested.

A. A Review of Seasonal Movements

1. Other Newfoundland Regions

a. Dyer's Gulch, Logy Bay. Dyer's Gulch is a small, rocky inlet in Logy Bay on the eastern edge of the Avalon Peninsula (Figure 1). The depth range in the gulch is approximately 4.5-18.5 m. According to Mr. V. Pepper (personal communication) winter flounders were present there from August, 1972, when his observations began, to the end of October. The flounders were absent from the gulch from November to mid-May of 1973, and then returned to stay until the end of the following September. On a sandy region outside the gulch at a depth of approximately 37 m Pepper observed winter flounders only during this summer period. In early November, 1973 he observed two fish at this location and suggested that they were remnants of the summer stock.

Thus the seasonal changes in flounder abundance in Dyer's Gulch bear greater similarity to those in St. Philips than to those in North Arm, since fish were present in the gulch only during the summer months and were absent through the winter.

b. Chapel Cove, Conception Bay. Chapel Cove is situated on the north headland at the mouth of Holyrood Bay (Figure 1). It is approximately the size of Broad Cove at St. Philips, and they have similar depths and bottom types.

Between March, 1972 and April, 1974 Dr. G. L. Fletcher (personal communication) noted the presence of winter flounders inside Chapel Cove at approximately 6-7.5 m from late spring until early winter. During the rest of the winter and spring fish were found in a sandy region outside the mouth of the cove in approximately 12-15.5 m of water. While fishing was conducted inside the cove it was not known if there were also flounder concentrations outside the cove. But during the winter and early spring flounders were largely absent inside Chapel Cove.

Thus flounder movements in Chapel Cove resembled those in St. Philips in that fish were present in shallow water near shore from late spring until early winter. But during the winter and spring when flounders were present outside Chapel Cove they were absent in the St. Philips region.

c. Long Pond, Conception Bay. Long Pond is located midway between North Arm and St. Philips (Figure 1). It is a shallow (1-2), salt water, barachois pond that opens into Conception Bay through a narrow gut which has been dredged to an average-depth of 6-7 m to form a small harbor at the mouth of the pond (Kennedy and Steele, 1971). Kennedy (1964) and Kennedy and Steele (1971) found winter flounders in Long Pond in 1-2 m from November until early June. During late June and July they moved into deeper water, and in August few flounders were observed in the dredged area (7-10 m). Since there is little food in Long Pond (Christie, cited by Kennedy and Steele, 1971), these authors suggested that the summer movements may represent a feeding migration. The flounders moved back into the dredged area in September and into the shallow water by October. Since the fish left Long Pond soon after spawning and returned as their gonads began to ripen, Kennedy (1964) suggested that movements of matures may be governed by the state of the gonads. The immatures behaved in the same manner as the matures.

Thus flounders were present during winter in shallow water near shore in Long Pond and North Arm (1973), but not in St. Philips, Dyer's Gulch, or Chapel Cove. During the summer months flounders moved out of Long Pond, as they did in North Arm in July and as the few in St. Philips did in August. This was not apparent in Dyer's Gulch or Chapel Cove.

2. <u>Regions to the Southwest of Newfoundland</u>.

In Northumberland Strait, which separates Prince Edward Island from New Brunswick and Nova Scotia, winter flounders are found in shallow, inshore water during spring and early summer at depths of approximately 4-9 m. By mid-summer they move to intermediate depths (15-24 m) as water temperatures in the shallows exceed 15° C. They are probably absent from the shallows during winter (McCracken, 1963).

Passamaquoddy Bay is on the New Brunswick-Maine border and opens into the Bay of Fundy. McCracken (1963) stated that winter flounders move from the shallows of Passamaquoddy Bay to nearby deeper water in winter as the shallows become colder than the deeper waters. Bigelow and Schroeder (1953) reported that flounders leave the shallows of the bay in winter unless the year is a very mild one. In late November Beamish (1966) found winter flounders in Passamaquoddy Bay at 46-64 m. Tyler (1971 b) stated that winter flounders are concentrated in the deepest areas of the bay when water temperatures are at their minimum. In the spring the flounders move back to the shallows where they are abundant in summer (McCracken, 1963). Wells *et al.* (1973) also found winter flounders in Brandy Cove, Passamaquoddy Bay in summer. The movements of the immatures in McCracken's study were similar to those of the matures. Tyler (1971 a) reported winter flounders on a sloping mud bottom in the bay at depths of 38-55 m throughout the year; their greatest abundance occurred in April and May. He suggested that they were moving through that region in April and May to nearby shallow areas to spawn.

St. Mary Bay, Nova Scotia is a long, gently shelving bay emptying westward into the southern side of the mouth of the Bay of Fundy (McCracken, 1963). Dickie and McCracken (1955) found that large and intermediate sized winter flounders are in deep water at the mouth of the bay in early spring. By late March and April the larger, mature fish spread along the sides of the bay, principally into the shallows on the south side where they spawn. In May and June they gradually move deeper toward the 10 fathom contour (18.5 m) where the intermediate sized fish concentrate earlier in the season. By late July and early August commercial sized fish seem to be almost evenly distributed from the shore to 20 fathoms (37 m). In October and November they appear to congregate around the 10 fathom contour and move towards the mouth of St. Mary Bay. McCracken (1963) concluded that flounders move from the shallows of St. Mary Bay to nearby deeper water in winter as the shallows become colder than the deeper waters, return to the shallows in spring, and are abundant there in summer.

Pubnico Harbour, Nova Scotia, which is near St. Mary Bay, is a long bay consisting primarily of shallow water flats. McCracken (1963) found winter flounders in the shallows of Pubnico Harbour in spring. In the summer he suggested that they move out of the bay to the shallow, cooler waters of the open coast as temperatures within the bay exceed 15° C. He stated that in winter they are probably absent from the shallows of the Pubnico Harbour region. McCracken's data indicate that movements of immatures and matures were similar, though the immatures may not have left the bay entirely during the summer.

At the head of St. Margaret's Bay, Nova Scotia there is a shallow inlet system. The mouth of this inlet system into the bay is called Head Harbour. Levings (1973), at a sampling depth of 17 m, found that winter flounders enter the Head Harbour region in the spring, remain through the summer, and withdraw gradually in the fall. He suggested that they spawn and feed at Head Harbour, and return to shallow waters for overwintering. Duman and DeVries (1974) found winter flounders at 3-10 m in Head Harbour in March (-1.2° C) a few days after the ice had begun to break up. Levins (cited by Duman and DeVries, 1974) stated that in the northern part of their range winter flounders occur during the winter in large numbers in ice covered shallow bays.

In the Gulf of Maine flounders are generally abundant in most shallow regions all summer, either to remain over winter or move to deeper water depending upon the temperature (Bigelow and Welsh, 1925; Bigelow and Schroeder, 1953). These authors reported an observation at Woods Hole that temperatures near freezing drive flounders down into slightly warmer water. The findings of Dr. J. J. Cech, Jr. (personal communication) are in agreement with this. He noted that in Casco Bay, Gulf of Maine most flounders, especially the larger, mature fish, are found in deeper water in late winter and early spring. In late spring and summer they apparently move into shallow areas and begin feeding. In shallow enclosed bays or harbors north of Cape Cod where extensive flats are exposed to high temperatures in summer and low temperatures in winter, flounders are present only in the spring and fall (Bigelow and Schroeder, 1953; Bigelow and Welsh, 1925).

Immediately north of Cape Cod, in the Massachusetts Bay region, McCracken (1963) concluded that winter flounders are present in shallow, inshore waters during summer and are found offshore in winter.

In these regions north of Cape Cod (but southwest of Newfoundland) which have been reported in the literature it appears that winter flounders are generally found inshore in shallow water in summer and in deeper water offshore in winter. The exceptions to this are the findings of Levings (1973), Duman and DeVries (1974), and Levins (cited by Duman and DeVries (1974), who reported winter flounders in shallow, inshore regions in winter. In comparing flounder movements in these regions to those in Newfoundland it appears that St. Philips, St. Thomas Cove, Dyer's Gulch, and Chapel Cove follow the general trend in that flounders in these locations are found in shallow coastal waters principally in the summer and fall but not in the winter. Flounder distribution in North Arm (1973) and Long Pond resembles that reported by Levings (1973) and Duman and DeVries (1974) in St. Margaret's Bay, in that flounders in these locations are found in very shallow waters during the winter months.

Seasonal movements of the winter flounder in regions as far south as Maryland have been documented in the literature. Bigelow and Welsh (1925) stated that migration of flounders out to sea in summer and back again in winter is more characteristic and regular south of Cape Cod than in the Gulf of Maine where movements are generally reversed (see above). In Great Harbor, which is near Woods Hole on the southern shore of Cape Cod, Lux and Nichy (1971) collected winter flounders in all months of the year at temperatures up to 21.1° C and depths of 0.6-4.6 m, but found them scarce in winter. They presumed that during winter the flounders move to estuaries to spawn. Seasonal changes in catches of immatures appear to have resembled those of the matures.

In the Weweantic River estuary, a small tidal tributary of Buzzard's Bay which borders on Cape Cod, Smith and Cole (1970) reported that adult winter flounders enter the estuary in late October, spawn from late February to mid-April, and move offshore by early May as temperatures exceed 15° C. Juveniles were found to inhabit the estuary throughout the year.

At the eastern end of Long Island, New York is a series of shallow bays, one opening into the next: Peconic Bay opens into Gardiners Bay which opens into Block Island Sound. The evidence indicates that in spring and summer, as water temperatures increase, the smaller flounders from Peconic and Gardiners Bays move to the offshore area at the mouth of Gardiners Bay soon after spawning; the larger fish move further offshore into Block Island Sound. In the fall and winter, with a decline in water temperatures, there appears to be a return movement to the inner bays. This is believed to be a spawning migration (Lobell, 1939). Tagging experiments by Neville and Perlmutter (1940) substantiated Lobell's findings. Merriman and Warfel (1948) reported the greatest catch per effort of sample hauls from the commercial trawl fishery in Block Island Sound from April to November, which corresponds to the above findings. McCracken (1963) concluded that fishing ceases in Peconic and Gardiners Bays as the bottom temperatures reach 13-14° C; winter flounders leaving these bays move into waters of less than 15° C. The flounders begin a return movement into the bays as the temperature decreases to about 15° C.

There is a spawning migration of adult winter flounders into the Mystic River estuary, Connecticut in January and February, principally into the upper estuary. In summer large fish are more common in deeper waters (which would be in Block Island Sound), perhaps because of uncomfortably high temperatures in the shallows. The seasonal movements of juveniles appear to be reversed, in that their numbers are high throughout the estuary in summer, but they seem to move out of the estuary during the winter (Pearcy, 1962). Huntsman and Sparks (1924) found that small winter flounders have a higher incipient lethal temperature than large fish, and Pearcy (1962) suggested that this may explain the difference in summer distribution beteeen juveniles and adults. The reason for juvenile emigration in the winter is unclear. Low temperature may not be the cause, since Pearcy (1961, 1962) noted a minimum lethal temperature of juveniles taken from the Mystic River estuary in winter of -1.0 to -1.5° C. Warfel and Merriman (1944) reported similar seasonal movements of juveniles in Morris Cove, Connecticut. Saila (1961) reported that adult winter flounders which were tagged in Green Hill Pond, Rhode Island in winter migrated to offshore waters in Block Island Sound in the summer. In the winter and early spring they returned to the shallow inshore waters to spawn.

In Long Island Sound it appears that many winter flounders move out of the enclosed western end in the spring and early summer. A shift in the commercial fishing effort indicates that flounders move from the middle to the eastern entrance of the sound between January and April (Lobell, 1939). Tagging studies in the middle of Long Island Sound by Lobell (1939) and Neville and Perlmutter (1940) in April showed that the majority of tagged flounders moved eastward. A number of these fish moved out of the sound to other areas such as adjoining Block Island Sound. Richards (1963) noted an absence of adults from Long Island Sound in winter at depths of 9 and 17 m. She suggested that they move to shallower water to spawn. She found that catches of juveniles were generally highest in early winter, which corresponds to Warfel and

Merriman's (1944) and Pearcy's (1962) findings for juveniles.

Lobell (1939) and Neville and Perlmutter (1940) reported on tagging experiments conducted in Great South Bay, Long Island, New York. These workers have demonstrated a migration out of the bay soon after spawning, chiefly through Fire Island Inlet, to inshore waters along the coast in spring and a return to the bay during fall and winter. McCracken (1963), comparing these results with temperatures reported by Perlmutter (1939), suggested that flounders move out of the bay before temperatures reach 20° C, but remain near shore in the cooler waters of the outer coast. While diving in the Fire Island Inlet region from July to early October, Olla *et al.* (1969) observed winter flounders there at temperatures of 17.2-24° C. The flounders were active and feeding up to 22.2° C. At higher temperatures they were inactive. Lobell (1939) reported an abrupt drop in the sport catch of winter flounders in Moriches Inlet, which is near Great South Bay, when water temperatures exceed 21° C. This may be due to inactivity as was reported by Olla *et al.* (1969).

In the bays of southern New Jersey winter flounders are very scarce in summer but are very plentiful there in winter. In Chesapeake Bay many are caught from November to early June, but none are taken in shallow water there in summer or early fall (Bigelow and Schroeder, (1953).

Winter flounders of 25-27.5 centimeters in length are common in shallow Isle of Wight and Assawoman Bays, near Ocean City, Maryland, from December to May, but they appear to migrate offshore in late spring (Schwartz, 1964).

Thus in nearly all regions south of Cape Cod which have been reported in the literature it appears that mature winter flounders migrate offshore to deeper water in spring and summer and then return to shallow inshore waters in the fall and winter. The seasonal movements of juveniles appear to be in the opposite direction (Pearcy, 1962; Richards, 1963; Warfel and Merriman, 1944). When compared to seasonal movements of winter flounders in Newfoundland regions it appears that those in Long Pond and to some extent those in North Arm resemble the movements of fish south of Cape Cod.

Two hypotheses have been presented in the literature to describe the seasonal movements of the winter flounder throughout its range. McCracken (1963) concluded that *P. americanus* has preferred temperature range of 12-15° C which controls its summer distribution. In summer north of Cape Cod he stated that flounders remain in shallow, inshore waters where temperatures do not exceed 15° C (for example Passamaquoddy and St. Mary Bays), but in regions which do exceed 15° C they move to deeper, cooler water (Northumberland Strait) or to shallow, cooler water (Pubnico Harbour). In summer south of Cape Code he stated that flounders move out of the shore zone to offshore waters as inshore temperatures exceed the preferred range. The reports of flounders in summer at 21.1° C in Great Harbor (Lux and Nichy, 1971) and at 17.2-24° C in Fire Island Inlet (Olla *et al.*, 1969) do not support McCracken's hypothesis. In winter north of Cape Cod McCracken stated that winter flounders move to deeper water as the shallows become colder than the deeper water. The reports of flounders in shallow water in winter in several northern regions (Duman and DeVries, 1974; Kennedy, 1964;

Kennedy and Steele, 1971; Levings, 1973; Levins, cited by Duman and DeVries, 1974; present observations) do not support McCracken's hypothesis. In the winter south of Cape Cod deeper water is also warmer than the shallows, but McCracken stated that flounders are found inshore probably because they are in a spawning condition.

Kennedy and Steele (1971) disagreed with McCracken's latitudinal differences in movement, since they observed movements in Long Pond to resemble those south of Cape Cod. They suggested that temperature preferences were of little significance in movements in Long Pond, as Levings (1973) concluded for flounder movements in St. Margaret's Bay. Kennedy and Steele proposed that in summer, winter flounders remain inshore in relatively open areas such as Passamaquoddy Bay, St. Mary Bay, Northumberland Strait, Long Island Sound, and Conception Bay, but that they leave estuaries, harbors, and barachois ponds throughout their range. They suggested the possibility that these summer movements may represent feeding migrations. It is apparent that Kennedy and Steele misinterpreted flounder movements in Northumberland Strait reported by McCracken (1963), and those in Long Island Sound reported by Lobell (1939). Therefore it does not appear that their hypothesis is entirely valid.

B. Movements in North Arm and St. Philips

In the present study a comparison of the data on (1) time of day, (2) state of the tide, (3) cloud cover, (4) water turbidity, and (5) salinity with winter flounder abundance revealed no relationship between these factors and flounder movement in North Arm or St. Philips.

McCracken (1963) and Levings (1973) reached the same conclusion regarding salinity.

The evidence indicates that winter flounders made no feeding migrations into North Arm. Feeding intensity remained relatively steady in the females from May to October and in the males from July to October (Figure 19) despite large fluctuations in flounder abundance (Figure 26). Also, it does not appear that flounders moved into North Arm at any time to take advantage of some particularly available food organism (Appendices G and H). The heavy feeding on capelin by flounders in Station A on June 19, causing a peak in the mean volume (Figures 17 and 20), was not an exception to this conclusion. By June 5 flounder abundance had already increased to the level of June 19, and, as is described later, this was apparently a spawning migration and not a feeding migration.

It does not appear that winter flounders made feeding migrations into St. Philips. The small peaks in abundance in Stations A and B during May, June, and July (Figure 27) appear to have been associated with spawning, though feeding was intensive (Figures 21 and 22). Winter flounders entered the St. Philips region in September and remained until December. But it is unlikely that this was a feeding migration since feeding intensity had begun to decline by September and ceased in early November (Figures 22-25). The data on the percentage volumes of the food organisms support the conclusion that winter flounders did not make feeding migrations into St. Philips. Peaks in abundance were never accompanied by high percentage volumes per sample of any group(s) of food organisms (Appendices I-K), suggesting that large numbers of fish were never present to take advantage of some particularly available food organism.

1. North Arm

Winter flounders were present in North Arm in the winter of 1973 (Figure 26). Water temperatures at that time were 0° C or below (Figure 6). Thus, as in other northern regions, the distribution of flounders in winter in North Arm does not support the hypothesis of McCracken (1963).

In March the flounders moved out of Stations A and B. Ice was blown into North Arm on March 7-10 and March 30 when water temperatures were below 0° C. Since the freezing temperature of the winter flounder in the presence of ice has been reported as $-1.4 \pm 0.1°$ C (Duman and DeVries, 1974), it may be that the flounders moved to deeper water to avoid freezing of their tissues.

The fish appeared to be concentrating in Station A in April. During April 19-26 ice was once again blown into North Arm, gouging the bottom in Station A. The flounders once again left the shallows, probably to avoid freezing and maybe to avoid mechanical injury due to the ice. Abundance in both stations remained relatively steady through May.

In June winter flounders moved into the shallowest regions of North Arm. The number of ripening or ripe and spent individuals indicate that the peak in spawning (Figures 11 and 12) coincided with this peak in flounder numbers, suggesting a spawning migration. The fact that Station A appears to have been the principal spawning ground in North Arm would account to some extent for the significant χ^2 obtained in comparing changes in abundance in Stations A and B (Table 6). The aggregation of flounders near the southern shore at the mouth of North Arm in June may also have been for spawning. Spawning migrations of winter flounders into the shallow, inshore waters of estuaries, bays, and ponds have been suggested or indicated by Dickie and McCracken (1955), Lobell (1939), Pearcy (1961, 1962), Perlmutter (1947), Saila (1961), Smith and Cole (1970), and Tyler (1971 a). Pearcy (1962) noted in the Mystic River estuary that the densest aggregations of adults were found in the principal spawning grounds of the upper estuary, as was true in North Arm. He reported otter trawl catches of nearly 1.0 fish per square meter there at the peak of spawning, as compared to a density of approximately 0.12 fish per square meter in North Arm Station A.

Winter flounders moved out of the shallows of North Arm in late June after spawning, and abundance there remained low through July. Kennedy (1964) and Kennedy and Steele (1971) reported a similar occurrence in Long Pond.

In August flounders returned to North Arm, concentrating principally in Station A. Accompanying this increase in abundance was an increase in the adjusted mean weight of both sexes (Figure 9). This indicates that the winter flounders which returned to North Arm in August were heavier than the few that remained there in July. Since the gonosomatic index in August was at a minimum in both sexes (Figure 13), the increase in body weight cannot be attributed to gonad growth. A logical conclusion is that after spawning in June the winter flounders left North Arm to feed elsewhere and returned as heavier fish in August. But since flounder abundance in August was greater than in June, some of the increase in body weight could also be attributed to the presence of heavier fish in August which were not in Station A in June. Kennedy and Steele (1971) suggested that flounders leave Long Pond during the summer to feed elsewhere since there is little food in the pond. The bottom types and broad food groups of flounders appear to be similar in North Arm and Long Pond, therefore the movement out of North Arm in late June may also have represented a feeding migration.

The inshore movement of flounders in August coincided with the peak in water temperature in North Arm of 11-13° C, which is similar to McCracken's preferred temperature range of 12-15° C. It is evident that the flounders moved rapidly into North Arm after the temperature reached 12° C. But during this brief peak in abundance the gonads of these fish began to ripen (Figures 11 and 12). Thus this return to shallow water may have been influenced by the reproductive condition of the gonads, as was suggested by Kennedy (1964), rather than by a temperature preference.

The reason for the rapid decline of flounder numbers in Station A in September, while temperatures were still 12° C, is not clear. It was noted in St. Philips at that time that the temperature in Station D had quickly risen to 13° C (Table 3). Since temperature changes in North Arm and St. Philips appear to have been similar it may be that the deeper waters in North Arm also warmed above 12° C in September. It is possible, therefore, that the flounders of the August/September peak in Station A spread into somewhat deeper waters of North Arm as they warmed to within McCracken's preferred temperature range. But the validity of this suggestion is tenuous. In Long Island waters and Northumberland Strait McCracken (1963) reported a similar spreading of flounders in the fall, though in the reverse direction, from offshore regions to the shore zone as the shallows cooled to within the preferred temperature range.

A severe storm was in progress on October 10/11, and flounder abundance in Stations A and B had declined sharply by that date. It is likely that the fish moved to deeper waters because of the turbulence, and then quickly returned. Gibson (1973) stated that larger fish may prefer and "select" regions of lower turbulence. He believed that his circumstantial evidence suggested that in conditions of high wave action fish do move into deeper water. In late October and early November flounders continued to move inshore into Station B. These fish had congregated in the deepest regions of Stations A and B, as they had the previous winter, so perhaps they were preparing for winter. They were well buried and their feeding had nearly ceased.

The majority of winter flounders emigrated from Station A by November 21, apparently because of a severe storm. The worst storm of the fall occurred on November 24-28, and was the likely cause of emigration from Station B.

Winter flounders were scarce in North Arm in the winter of 1974, in contrast to the previous winter. The difference in abundance appears to be due to the much stronger winds and the resulting turbulence in January and February, 1974 (Figure 8). Easterly and northeasterly gusts were much more common during the winter of 1974, and they blew directly into North Arm. Gibson (1973) noted that the European plaice, *Pleuronectes platessa* (L.), moves offshore in winter. He suggested a few possible causes, one of which was avoidance of greater turbulence in the fall and winter caused by storms which are more frequent at that time of year. Green (1974) suggested that cunners, *Tautogolabrus adspersus* (Walbaum), were killed by a winter storm which carried ice crystals from the surface into the water column, freezing the fish. Thus offshore movement of winter flounders in winter in response to turbulence may have the adaptive significance of preventing freezing of their tissues. Therefore the winter flounders of North Arm may have remained in deeper water during the winter of 1974 as a result of turbulence.

The concentration of winter flounders found near Station A on April 8, 1974, may have represented the beginning of a migration into the shallows of North Arm as the high winds and heavy turbulence of winter began to decline. A similar immigration into Station A occurred the previous April after the flounders had been forced out of Station A by ice.

These seasonal movements which have been observed in North Arm suggest what could be a basic pattern of movement there. It may be that winter flounders remain in the shallow waters of North Arm through the fall, winter, and spring until the end of the spawning season unless they are forced out by turbulence or ice. If a winter is particularly severe they may remain in deeper water until the spring. After spawning they move elsewhere to feed for the summer. In the early fall, as the gonads begin to ripen and/or water temperatures are at a maximum, the flounders move back into the shallow waters of North Arm to remain there until the following spring spawning. When these fish leave the shallows because of turbulence or ice it seems unlikely that they would move much beyond the mouth of North Arm (Figure 2). The depths in that region, approximately 18-22 m, would take them out of the reach of most turbulence and ice. Slightly further offshore the bottom rapidly drops to 55-74 m, depths which would be of little advantage to the fish at that time. Where the stock goes to feed in the summer is unknown.

2. St. Philips

Winter flounders were absent from St. Philips in the winter and early spring of 1973 (Figure 27), probably because of turbulence and perhaps ice. January and February were relatively windy months and northerly onshore winds were very common from January to April (Figure 8). The result was rough seas through much of this period, with ice frequently jamming into the St. Philips region.

Some fish moved into the shallowest regions of St. Philips in May and June. The number of ripening or ripe and spent fish (Figure 14) and the shifts in flounder distribution suggest that the fish first congregated in Station B and similar depths at St. Philips, moved into very shallow water in Station A and inshore of Station B to spawn, and then moved off slightly into the vicinity of Station B as spent fish. These flounders remained and fed relatively heavily into July (Figures 21-25).

Winter flounders moved out of the St. Philips region in August.

The cause of this emigration is not apparent. A very large concentration of flounders was found in August at nearby St. Thomas Cove. These fish were concentrated mainly at depths of 7.5-12 m on a sandy bottom. Within this region of concentration there were large quantities of what appeared to be capelin eggs mixed in the sand. The presence of capelin eggs at these depths is unusual, but not unknown (Mr. R. Hooper, personal communication). Seven flounders were collected from a rocky bottom just inshore of the maximum flounder concentration where the capelin eggs were situated. The stomachs or intestines of all seven fish were full of these eggs. The evidence therefore suggests that this very large aggregation of flounders had entered the St. Thomas Cove region to feed on the masses of capelin eggs available there. That no flounders were present at nearby St. Philips supports this conclusion. Capelin eggs were not observed there, and only two of sixteen flounders collected there in July had been feeding on capelin eggs (Appendices I-K). Thus it may be that the St. Philips flounders moved elsewhere in August, perhaps to St. Thomas Cove, also to feed on some plentiful food supply such as capelin eggs.

It is interesting to note that Kennedy (1964) and Kennedy and Steele (1971) also found winter flounders to be present at St. Thomas Cove (Horse Cove) in August, 1963. The abundance of the flounders was not mentioned in these papers, but two dives were required to collect 26 fish. This may be an indication that flounders were not as abundant as in August, 1973 when 26 fish could have been speared in a matter of minutes. These authors found no fish eggs or fish remains in the stomachs of the flounders they collected, unlike the present study.

The difference in flounder abundance may have been due to the difference in food supply.

In early September winter flounders returned to the St. Philips region. Flounder abundance in Station D increased quickly between August 24 and September 10 (Appendix M) as the water temperature there rose from 9.5° to 13° C. Flounders then moved rapidly into the shallower stations while water temperatures there were 12-13°C. A possible, though tenuous, explanation for this immigration is that winter flounders dispersed from inshore regions of concentration, such as St. Thomas Cove, into St. Philips as coastal waters warmed to within McCracken's (1963) preferred temperature range of 12-15° C.

Winter flounder abundance remained steady in the inshore shallows of St. Philips through September. In mid-October it appears that a severe storm caused flounders to move from shallower water, including Station B, to the slightly deeper water in Station C. By November 1 the flounders of St. Philips had returned to their pre-storm distribution, which may be supporting evidence of a brief offshore movement during the storm.

In mid-November flounder abundance in the shallows of St. Philips increased, perhaps due to a slight inshore shift of the stock. In late November the worst storm of the fall (November 24-28) is the likely reason that winter flounders rapidly moved out of the shallows at St. Philips. They were not found in Station D, so their new location remains unknown. By mid-December the stock had returned to the shore zone. Why the fish returned to the shallows at St. Philips after the severe fall storms is not apparent.

Winter flounders were absent from St. Philips in the winter of 1974. The strong northerly winds during that period (Figure 8) which blew directly onshore at St. Philips created heavy seas and much turbulence in the bottom waters. This turbulence is the likely reason for flounder emigration from St. Philips in the winter of 1974.

A basic pattern of seasonal movements of winter flounders in St. Philips and neighboring regions is difficult to determine from the evidence which has been gathered. That the flounders move offshore in winter seems apparent since very few were observed throughout St. Philips in the winters of 1973 and 1974 or in the St. Thomas Cove region in December, 1972. Also, there are relatively few salt water ponds, estuaries, etc. along the southern coast of Conception Bay to accommodate these stock(s) of flounders in winter. It may be that in the winter months flounders from the St. Philips and St. Thomas Cove regions move southwestward along the coastline to the Topsail Cove and Manuels River area, or maybe further, and then move offshore to deeper waters (Figure 1). It seems doubtful that the fish would move directly offshore from St. Philips or St. Thomas Cove, because the bottom in these regions drops steeply off to approximately 75-120 m, and appears to consist principally of rocks and gravel from about 20 m down (Canadian Hydrographic Service maps; personal observations). These depths are generally greater than those which have been reported for *P. americanus* in the literature (Beamish, 1966; Bigelow and Schroeder, 1953; Bigelow and Welsh, 1925; Tyler , 1971a). But further down the coast the offshore waters are shallower, and there are large stretches of sand amongst the rocks and gravel (Canadian Hydrographic Service maps).

Flounders which moved into this region in winter would be at previously reported depths (Beamish, 1966; Bigelow and Schroeder, 1953: Bigelow and Welsh, 1925; McCracken, 1963; Saila, 1961; Tyler, 1971a) and on previously reported bottom sediments (Bigelow and Schroeder, 1953; Bigelow and Welsh, 1925; Tyler, 1971a) for that season and would be beyond the reach of most turbulence. In the late spring it seems likely that these flounders would move inshore to spawn on the mud and sand bottom in the Manuels River to Topsail Cove region and nearby areas, with some spawning occurring further along the coast. After spawning perhaps they disperse along the coastline in search of food (for example to St. Thomas Cove) and into regions within McCracken's (1963) preferred temperature range of 12-15°C (for example St. Philips in September).

C. A General Scheme of Seasonal Movements

Seasonal movements of the winter flounder appear to be governed by different factors at different times of the year. It is the opinion of the present author that McCracken (1963) was correct when he concluded that flounders throughout their range leave shallow inshore waters in the summer when temperatures are high. But Kennedy and Steele (1971) found that flounders left Long Pond in summer where temperatures did not reach 12° C. They suggested that this may have been a feeding migration. A similar occurrence was noted in North Arm and it was also concluded that this emigration was for the purpose of feeding. McCracken found that flounders remain in the shallows of Passamaquoddy Bay in summer, and temperatures there did not reach 15°C in his study. Also, the intertidal zone of the bay has been proposed to be a major feeding ground for *P. americanus* (Tyler, 1971b; Wells *et al.*, 1973). It may be, therefore, that in the summer months winter flounders remain in shallow, inshore waters if temperatures are not excessive (perhaps 15°C or less) and if sufficient food is available to maintain the stock. The temperature factor may not be as important in juveniles, since there is evidence to indicate that they remain in the shallow waters of coves and estuaries in the summer months in more southerly regions (Lux and Nichy, 1971; Pearcy, 1962; Warfel and Merriman, 1944), while the adults move offshore to deeper, cooler waters. The fact that juveniles have a higher incipient lethal temperature than adults may account for their difference in summer distribution (Pearcy, 1962).

In the fall and early winter the gonads of winter flounders are ripening. Throughout their range it appears that the fish remain in or move to shallow water where they will spawn that winter or the following spring. McCracken (1963), Kennedy and Steele (1971), and the present author are in agreement that winter flounders are found inshore in winter in more southerly waters probably because they are in a spawning condition. Evidence indicates that juveniles in these regions leave the immediate shore zone in winter (Lux and Nichy, 1971; Pearcy, 1962; Warfel and Merriman, 1944), unlike the adults, but the reason for this emigration is not known. It is apparent that McCracken was not entirely correct when he concluded that flounders in northern regions move to deeper water in the winter as the shallows become colder than the deeper, since flounders have been reported in shallow, inshore waters in winter in Nova Scotia and Newfoundland. It may be that during the winter months flounders in the northern part of their range remain in shallow, inshore waters which are protected from turbulence, such as salt water ponds and estuaries, but they are driven from exposed areas by the turbulence resulting from winter storms. Drifting pack ice also appears to be a cause of offshore movement in winter.

Offshore movement in response to winter storms would appear to bear adaptive significance for two reasons: (1) at very low temperatures the flounders would avoid freezing caused by contact with ice crystals, and (2) the flounders do not feed in winter, yet the males maintain their testes at near maximum size and the ovaries of the females are still growing at the expense of other body tissues. Therefore an additional expenditure of energy due to the stress of turbulence would be to their disadvantage in winter and may cause offshore movement to deeper, quieter water. But if a winter is calm, or the shallows in which flounders are located are protected from winds and turbulence, it would seem to their advantage to remain inshore and to conserve the energy expenditure required in offshore movement.

In the spring adults in these northern regions remain in or return to shallow water to spawn.

In brief, the suggested scheme may be summarized as follows. In the summer months adult winter flounders remain in the shallow shore zone where water temperatures are not excessive and where sufficient food is available to support the population. Juveniles may remain inshore at higher temperatures. In the fall and early winter, as their gonads are ripening, flounders remain in or move to shallow water where they will spawn that winter or spring. In the winter months adults in more southern parts of their range remain inshore because they are ready to spawn. Juveniles move out of the shallows there for reasons unknown. In northern regions flounders remain inshore in protected waters in winter, but move offshore from exposed coasts to avoid turbulence and drifting pack ice. In unusually calm winters perhaps flounders do not leave the shallows along exposed coastlines. In these northern regions the flounders either remain in or return to the shore zone to spawn in the spring.

Regions in which seasonal movements of the winter flounder have been reported and the causes appear to fit the suggested scheme are North Arm, St. Philips and St. Thomas Cove (present observations), Long Pond (Kennedy, 1964; Kennedy and Steele, 1971), and Passamaquoddy Bay (McCracken, 1963; Tyler, 1971a). Other regions which appear to fit the model though information on either water temperature, food, or turbulence are lacking are Dyer's Gulch (Pepper, personal communication), Chapel Cove (Fletcher, personal communication), St. Margaret's Bay, Nova Scotia (Duman and DeVries, 1974; Levings, 1973), St. Mary Bay, Nova Scotia (Dickie and McCracken, 1955; McCracken, 1963), Northumberland Strait and Pubnico Harbor, Nova Scotia (McCracken, 1963), the Gulf of Maine (Bigelow and Schroeder, 1953; Bigelow and Welsh, 1925), the Weweantic River estuary, Massachusetts (Smith and Cole, 1970), Long Island waters, New York (Lobell, 1939; Neville and Perlmutter, 1940), Block Island Sound (Merriman and Warfel, 1948; Richards, 1963) the Mystic River estuary, Connecticut (Pearcy, 1962), Morris Cove, Connecticut (Warfel and Merriman, 1944), Green Hill Pond, Rhode Island (Saila, 1961), southern New Jersey and Chesapeake Bay (Bigelow and

Schroeder, 1953), and Isle of Wight and Assawoman Bays, Maryland (Schwartz, 1964).

Reports of movements in the literature which do not appear to fit the present scheme are those of Lux and Nichy (1971) in Great Harbor, Massachusetts and Olla *et al.* (1969) in Fire Island Inlet, Long Island. These authors found winter flounders in shallow water in the summer at water temperatures of 21.1°C and 17.2–24°C respectively. Why these fish did not move to deeper water, as those in other southerly regions do in summer, is unknown.

SUMMARY

Seasonal movements of the winter flounder were examined at North Arm and St. Philips in Conception Bay, Newfoundland from February, 1973 to March, 1974. Movements were inferred from changes in flounder abundance at different stations within each study site. Abundance at a station on a given date was determined by counting fish on a fixed area of bottom using SCUBA. A modest tagging program was conducted in an attempt to differentiate stocks within each study site. Environmental and physiological factors were compared with movements in an attempt to determine their causes.

The range in bottom water temperature was -1° to 13°C in North Arm and -1.5° to 13.5°C at St. Philips. Winds were strongest during the winter months. Wind speeds were much greater in the winter of 1974 than in that of 1973. Pack ice drifted into and out of the shore zone through March and April, 1973, extending deep into the water column and occasionally scraping the bottom. Severe storms occurred during the fall, causing much turbulence in the bottom waters.

The adjusted mean weight of winter flounders from both study sites generally increased from a low level in the early summer to a maximum in the fall, and then decreased again in late fall and early winter. In January to March, 1974 the few flounders which remained in North Arm were significantly heavier than those collected in December.

The peak of spawning in both study sites occurred in June. Shallow Station A was the principal spawning ground in North Arm.

Little spawning occurred at St. Philips. Flounders in North Arm began ripening in August. Those entering the St. Philips area in September were already ripening. The males in both study sites ripened more quickly than the females.

Winter flounders in both study sites began to feed in early May. Feeding in North Arm was relatively intensive until October, while at St. Philips there was a noticeable decline by September. Feeding ceased in both study sites in November.

Seasonal movements of winter flounders from Newfoundland to Maryland are briefly reviewed. Two hypotheses presented in the literature to describe seasonal movements of winter flounders throughout their range are discussed.

Seasonal movements of winter flounders in North Arm and St. Philips are indicated by statistically significant changes in abundance which occurred with time. It appears that these movements were not related to the time of day, the state of the tide, cloud cover, water turbidity, or salinity. It also appears that flounders made no feeding migrations into North Arm or St. Philips.

Winter flounders, present in North Arm in the winter of 1973, left the shallows in the spring as pack ice entered the region. This emigration may have prevented freezing of the fish. In June flounders moved into the shallowest regions of North Arm, spawned, and then moved out again apparently to feed. Their return in August coincided with the peak in water temperature and the initiation of ripening of the gonads. Many flounders left Station A in September as deeper waters warmed to within McCracken's (1963) preferred temperature range of 12-15°C. In October most of the flounders remaining in the shallows moved to deeper water, apparently in response to turbulence resulting from a severe storm. The fish soon returned, moving into the deepest regions of Stations A and B. These flounders again moved out of Stations A and B in November during severe storms. Strong winds and resulting turbulence are the likely reasons that winter flounders did not return to the shallows of North Arm in the winter of 1974. This offshore distribution in winter in response to turbulence may prevent freezing of the fish resulting from contact with ice crystals. A concentration of flounders was found near Station A in April as the high winds and heavy turbulence of the winter began to decline.

Winter flounders were absent from St. Philips in the winter and early spring of 1973, probably because of turbulence and ice. Some fish moved into shallow water there in May and June, spawned, and remained into July. These fish left St. Philips in August, perhaps moving to St. Thomas Cove (where flounders were abundant) or other nearby areas to feed on some plentiful food supply such as capelin eggs. In early September flounders returned to St. Philips in what may have been a dispersal from inshore regions of concentration, such as St. Thomas Cove, as coastal waters warmed to within McCracken's (1963) preferred temperature range of 12-15°C. From October to December winter flounders left the shallows of St. Philips during severe storms and returned to the shore zone as the turbulence subsided. Flounders were absent from St. Philips in the winter of 1974, probably because of the strong northerly winds and resulting turbulence of that winter.

The following general scheme of seasonal movements of the winter flounder throughout its range is suggested. In summer adult flounders remain in shallow water where conditions of temperature and food are suitable. Juveniles may remain inshore at higher temperatures. In the fall and early winter, flounders remain in or move to shallow water where they will spawn that winter or spring. In winter adults in more southerly regions remain inshore to spawn. Juveniles leave the shallows there. In northern regions flounders remain in protected shallows in winter, but leave exposed coasts to avoid turbulence and drifting pack ice. In these northern regions flounders either remain in or return to the shore zone to spawn in the spring.

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APPENDIX A

North Arm (all stations combined): results of the analysis of covariance and Duncan's new multiple range test of the length-weight data of each sex divided into intervals of time. In Duncan's test the time intervals are ranked according to decreasing adjusted mean weight. Any two means underscored by the same line are not significantly different (Steel and Torrie, 1960). (a) males, (b) females.

(a) North Arm, Males

(1) Analysis of covariance:

Time Interval (group)	Number Fish in Group	Adjusted Mean Weight (grams)
Jan., Feb., Mar. 1973	13	367
Apr., May	10	372
June	11	357
July	15	333
Aug.	10	385
Sept.	10	405
Oct.	14	408
Nov.	17	404
Dec.	22	361
Jan., Feb., Mar. 1974	8	403

adjusted F = 3.63 probability (F) = 0.000.

(2) Duncan's new multiple range test:

Oct.	Sept.	Nov.	Jan. Feb. Mar. 1974	Aug.	April May	Jan. Feb. Mar. 1973	Dec.	June	July

(b) North Arm; Females

(1) Analysis of covariance:

Time Interval (group)	Number Fish in Group	Adjusted Mean Weight (grams)
Jan., Feb., Mar. 1973	18	501
Apr., May	10	567
June	12	549
July	11	509
Aug.	6	567
Sept.	21	537
Oct.	17	535
Nov.	19	470
Dec.	13	465
Jan., Feb., Mar. 1974	5	574

adjusted F = 3.13 probability (F) = 0.002

(2) Duncan's new multiple range test:

Jan. Feb. Mar. 1974	Apr. May	Aug.	June	Sept.	Oct.	July	Jan. Feb. Mar. 1973	Nov.	Dec.

APPENDIX B

St. Philips (all stations combined): results of the analysis of covariance and Duncan's new multiple range test of the length-weight data of each sex divided into intervals of time. In Duncan's test the time intervals are ranked according to decreasing adjusted mean weight. Any two means underscored by the same line are not significantly different (Steel and Torrie, 1960). (a) males, (b) females.

(a) St. Philips, Males

(1) Analysis of covariance:

Time Interval (group)	Number Fish in Group	Adjusted Mean Weight (grams)
May, June, July	10	501
Sept.	11	527
Oct.	21	556
Nov.	27	501
Dec.	12	507

adjusted F = 3.37 probability (F) = 0.014

(2) Duncan's new multiple range test:

Oct.	Sept.	Dec.	May June July	Nov.

(b) St. Philips, Females

(1) Analysis of covariance:

Time Interval (group)	Number Fish in Group	Adjusted Mean Weight (grams)
May	11	587
June	7	592
July	12	613
Sept.	11	644
Oct.	13	676
Nov.	18	637
Dec.	7	615

adjusted F = 1.82 probability (F) = 0.108

(2) Duncan's new multiple range test:

Oct.	Sept.	Nov.	Dec.	July	June	May

APPENDIX O

North Arm: average gonosomatic index (gonad weight expressed as a percentage of the total body weight = G.S.I.) for each sex in each sample. The numbers of males and females refer to mature fish only.

Date	Station A				Station B				Station D			
	No. Males	No. Females	G.S.I. Males	G.S.I. Females	No. Males	No. Females	G.S.I. Males	G.S.I. Females	No. Males	No. Females	G.S.I. Males	G.S.I. Females
Jan. 25	3	2	8.3	16								
Feb. 2	2	3	11	12.7								
Feb. 14	5	6	9.3	14								
Feb. 22/23	0	0	-	-	0	0	-	-				
Mar. 27/26	3	8	9.3	16	0	0	-	-				
Apr. 10/11/13	6	2	8.3	20	0	0	-	-	0	0	-	-
May 10/11	1	1	8.4	19	2	0	8.6	-				
May 24/23	1	8	9.6	17	0	0	-	-				
June 5/6	5	3	8.1	18	0	3	-	18				
June 19/20/22	3	4	4.1	10	3	2	5.7	13	2	0	7.4	-
July 3/3	3	3	2	3	2	1	3	2.7				
July 18/18	4	2	2	2	4	1	1	2.6				
July 31/Aug. 1	2	4	0.6	3	0	0	-	-				
Aug. 14/15/17	1	1	1	2	2	0	1	-	3	1	0.8	2
Aug. 28/29	4	3	1	2.9	4	2	1.3	3.2				
Sept. 11/12	1	7	4.5	3.7	3	4	3.4	4.1				
Sept. 25/26	2	6	4.2	5.0	4	4	6.4	4.5				

Date	Station A				Station B				Station D			
	No. Males	No. Females	G.S.I. Males	G.S.I. Females	No. Males	No. Females	G.S.I. Males	G.S.I. Females	No. Males	No. Females	G.S.I. Males	G.S.I. Females
Oct. 10/11	1	6	9.7	5.9	4	3	11.5	5.6				
Oct. 24/25	4	5	12.1	8.4	5	3	13.8	6.7				
Nov. 7/8	5	6	10.0	7.7	4	2	12.6	6.8				
Nov. 21/22	4	6	6.9	9.3	5	5	9.7	8.5				
Dec. 5/6	6	4	8.4	8.5	6	2	9.0	10.8				
Dec. 17/18	7	3	8.4	10.4	3	5	10.7	9.3				
Jan. 19	0	0	-	-	-	-	-	-				
Jan. 30/Feb. 1	2	1	9.2	13.8	6	2	9.2	14.0				
Mar. 1/2	0	2	-	16.7	0	0	-	-				
Apr. 8	12*	11*	8.8	15.3	-	-	-	-				

*Collected by diving staff of Marine Sciences Research Laboratory.

APPENDIX D

North Arm (all stations combined): average gonosomatic index (gonad weight expressed as a percentage of the total body weight = G.S.I.) for each sex divided into intervals of time. The numbers of males and females refer to mature fish only.

Date	Number Males	Number Females	G.S.I. Males	G.S.I. Females
Jan., Feb., Mar.	13	18	9.4	15
April, May	10	10	8.5	19.2
June	11	12	6.4	14.5
July	15	11	1.6	2.5
Aug.	10	6	1.2	2.9
Sept.	10	21	4.9	4.3
Oct.	14	17	12.4	6.7
Nov.	17	19	10.3	8.3
Dec.	22	13	8.9	10.1
Jan., Feb., Mar.	8	5	9.2	15.0
April*	12	11	8.8	15.3

*Collected by diving staff of Marine Sciences Research Laboratory.

APPENDIX E

St. Philips: average gonosomatic index (gonad weight expressed as a percentage of the total body weight = G.S.I.) for each sex in each sample. The numbers of males and females refer to mature fish only.

Date	Station A				Station B				Station C				Station D			
	No. M.	No. F.	G.S.I M.	G.S.I F.	No. M.	No. F.	G.S.I M.	G.S.I F.	No. M.	No. F.	G.S.I M.	G.S.I F.	No. M.	No. F.	G.S.I M.	G.S.I F.
Feb. 7/7	0	0	-	-	0	0	-	-								
Mar. 20/19/21	0	1	-	1.8	0	0	-	-					0	0	-	-
Apr. 18/18	0	0	-	-	0	0	-	-								
May 1/6	0	0	-	-	1	1	9.4	26								
May 18/16	1	4	5.9	12.0	0	0	-	-								
May 29/30/June 1	1	3	6.3	8.2	0	3	-	16.8					0	0	-	-
June 12/11	1	1	2.9	20	1	3	10	21.1								
June 26/27	0	0	-	-	1	3	1	2.8								
July 10/11/12	0	3	-	2.1	1	2	0.4	2	1	3	0.7	2.6				
July 24/25/25	0	0	-	-	0	2	-	2	2	2	0.6	2				
Aug. 7/8/8	0	0	-	-	0	0	-	-	0	0	-	-				
Aug. 21/22/22/24	0	0	-	-	0	0	-	-	0	0	-	-	0	0	-	-
Sept. 4/6/6/10	0	1	-	3.0	2	0	1.7	-	1	3	0.7	3.5	2	4	2.4	5.1
Sept. 18/19/19	1	1	0.7	4.2	2	5	3.6	5.2	6	1	6.1	4.8				
Oct. 3/4/4	0	5	-	6.4	6	2	9.0	8.0	6	2	13.5	5.4				
Oct. 17/18/18	0	0	-	-	7	0	13.9	-	2	4	17.6	9.9				
Oct. 31/Nov. 1/1	0	0	-	-	6	2	15.6	10.6	6	1	15.9	8.9				

Date	Station A				Station B				Station C				Station D			
	No. M.	No. F.	G.S.I M.	G.S.I F.	No. M.	No. F.	G.S.I M.	G.S.I F.	No. M.	No. F.	G.S.I M.	G.S.I F.	No. M.	No. F.	G.S.I M.	G.S.I F.
Nov. 15/16/16	0	0	–	–	6	3	12.2	11.3	2	6	14.4	9.9				
Nov. 29/29/30					3	2	12.6	15.8	4	4	12.5	16.5	0	0	–	–
Dec. 13/14					8	1	11.9	17.6	4	6	12.3	14.5				
Jan. 24/25					0	0	–	–	0	0	–	–				
Feb. 8/8					0	0	–	–	1	0	9.2	–				

APPENDIX F

St. Philips (all stations combined): average gonosomatic index (gonad weight expressed as a percentage of the total body weight = G.S.I.) for each sex divided into intervals of time. The numbers of males and females refer to mature fish only. May, June, and July are combined in the males.

Date	Number Males	Number Females	G.S.I. Males	G.S.I. Females
May		11		13.5
June	10	7	3.8	13.1
July		12		2.2
Aug.	-	-	-	-
Sept.	11	11	4.3	4.4
Oct.	21	13	12.7	7.6
Nov.	27	18	14.0	12.3
Dec.	12	7	12.0	14.9

APPENDIX G

North Arm, Station A: the percentage volume of each food group per sample.

	Date																									
	J 25	F 2	F 14	F 22	M 27	A 10	M 10	M 24	J 5	J 19	J 3	J 18	J 31	A 14	A 28	S 11	S 25	O 10	O 24	N 7	N 21	D 5	D 17	J 19	J 30	M 1
unidentifiable organic matter	100	100	100	–	100	100	10	33	63	1	49	56	41	80	54	40	73	19	42	32	100	48	100	–	100	0
debris	0	0	0	–	0	0	1	2	5	1	2		3						1	2	0	4	0	–	0	0
algae	0	0	0	–	0	0	14	3	0	0	3	33	0	7	2	14	3	29	0	1	0	2	0	–	0	0
Coelenterata																										
Actiniaria	0	0	0	–	0	0	0	16	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	–	0	0
Mollusca																										
Polyplacophora	0	0	0	–	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	–	0	0
limpets	0	0	0	–	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0
other Gastropoda	0	0	0	–	0	0	1	0	2	0	5	0	0	0	8	0	0	0	0	0	0	0	0	–	0	0
Pelecypoda	0	0	0	–	0	0	63	1	5	0	4	11	3	10	1	2	3	2	0	0	0	0	0	–	0	0
Annelida																										
sand tube Polychaeta	0	0	0	–	0	0	0	1	0	0	0	0	0	0	1	1	15	2	6	12	0	46	0	–	0	0
other Polychaeta	0	0	0	–	0	0	7	15	2	0	34	0	45	2	32	40	1	48	52	3	0	0	0	–	0	0
Oligochaeta	0	0	0	–	0	0	0	1	0	0	0	0	0	1	4	3	1	0	0	0	0	0	0	–	0	0
Crustacea																										
Cumacea	0	0	0	–	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0
Isopoda	0	0	0	–	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0

	Date																									
	J 25	F 2	F 14	F 22	M 27	A 10	M 10	M 24	J 5	J 19	J 3	J 18	J 31	A 14	A 28	S 11	S 25	O 10	O 24	N 7	N 21	D 5	D 17	J 19	J 30	M 1
Crustacea (cont.)																										
Amphipoda	0	0	0	–	0	0	1	22	21	0	0	0	2	0	0	0	0	0	0	0	0	0	0	–	0	0
Mysidacea	0	0	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0
Brachyura	0	0	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0
unidentified Crustacea	0	0	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0
Echinodermata																										
<u>S. droebachiensis</u>	0	0	0	–	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	–	0	0
Asteroidea	0	0	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0
Ophiuroidea	0	0	0	–	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	–	0	0
Fish eggs																										
capelin eggs	0	0	0	–	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0
<u>P. americanus</u> eggs	0	0	0	–	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0
Fish remains																										
capelin	0	0	0	–	0	0	0	0	0	93	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0
unidentified fish remains	0	0	0	–	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	–	0	0

APPENDIX H

North Arm, Station B: the percentage volume of each food group per sample.

	Date																				
	F 23	M 26	A 11	M 11	M 23	J 6	J 20	J 3	J 18	A 1	A 15	A 29	S 12	S 26	O 11	O 25	N 8	N 22	D 6	D 18	F 1
unidentifiable organic matter	–	–	–	21	–	17	33	*	36	62	39	76	87	68	47	56	91	100	100	100	100
debris	–	–	–	6	–	40	3	*	4												
algae	–	–	–	36	–	7	42	35	48	14	47	3	0	1	4	0	0	0	0	0	0
Coelenterata																					
Actiniaria	–	–	–	0	–	25	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0
Mollusca																					
Polyplacophora	–	–	–	0	–	0	0	0	0	0	1	1	0	11	0	3	0	0	0	0	0
limpets	–	–	–	0	–	0	0	3	0	0	0	0	0	0	0	2	0	0	0	0	0
other Gastropoda	–	–	–	0	–	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0
Pelecypoda	–	–	–	0	–	1	2	1	1	0	3	4	3	3	3	3	0	0	0	0	0
Annelida																					
sand tube Polychaeta	–	–	–	0	–	3	6	3	2	0	2	5	4	9	19	26	9	0	0	0	0
other Polychaeta	–	–	–	6	–	3	11	1	3	24	0	1	0	2	11	3	0	0	0	0	0
Oligochaeta	–	–	–	0	–	0	0	0	0	0	0	7	4	6	2	1	0	0	0	0	0
Crustacea																					
Cumacea	–	–	–	24	–	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Isopoda	–	–	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Date																				
	F 23	M 26	A 11	M 11	M 23	J 6	J 20	J 3	J 18	A 1	A 15	A 29	S 12	S 26	O 11	O 25	N 8	N 22	D 6	D 18	F 1
Crustacea (cont.)																					
Amphipoda	–	–	–	3	–	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Mysidocea	–	–	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyura	–	–	–	0	–	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
unidentified Crustacea	–	–	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinodermata																					
<u>Strongylocentrotus droebachiensis</u>	–	–	–	0	–	0	0	0	0	0	0	1	1	0	7	6	0	0	0	0	0
Asteroidea	–	–	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophiuroidea	–	–	–	0	–	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fish eggs																					
capelin eggs	–	–	–	0	–	0	0	*	0	0	0	0	0	0	0	0	0	0	0	0	0
<u>P. americanus</u> eggs	–	–	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fish remains																					
capelin	–	–	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
unidentified fish remains	–	–	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*July 3 : 57% = mixture of unidentified organic matter, debris, and capelin eggs.

APPENDIX I

St. Philips, Station A: the percentage volume of each food group per sample.

	Date																		
	F 7	M 20	A 18	M 1	M 18	M 29	J 12	J 26	J 10	J 24	A 7	A 21	S 4	S 18	O 3	O 17	O 31	N 15	N 28
unidentifiable organic matter	–	0	–	–	1	10	28	32	38	12	–	–	32	25	29	–	–	–	–
debris	–	0	–	–	0	0	2	6	5	2	–	–				–	–	–	–
algae	–	0	–	–	49	5	5	14	0	0	–	–	0	0	4	–	–	–	–
Coelenterata																			
Actiniaria	–	0	–	–	0	5	17	0	1	20	–	–	14	0	0	–	–	–	–
Mollusca																			
Polyplacophora	–	0	–	–	1	11	17	22	19	5	–	–	23	0	5	–	–	–	–
limpets	–	0	–	–	0	35	7	10	4	5	–	–	0	0	3	–	–	–	–
other Gastropoda	–	0	–	–	0	0	0	0	0	0	–	–	0	0	0	–	–	–	–
Pelecypoda	–	0	–	–	47	0	0	0	0	0	–	–	[illegible]	0	0	–	–	–	–
Annelida																			
sand tube Polychaeta	–	0	–	–	0	1	0	0	0	0	–	–	0	0	0	–	–	–	–
other Polychaeta	–	0	–	–	0	18	10	4	7	44	–	–	5	50	5	–	–	–	–
Oligochaeta	–	0	–	–	0	2	0	0	0	0	–	–	5	0	0	–	–	–	–
Crustacea																			
Cumacea	–	0	–	–	0	0	0	0	0	0	–	–	0	0	0	–	–	–	–
Isopoda	–	0	–	–	0	0	0	0	0	0	–	–	0	0	0	–	–	–	–

	Date																		
	F 7	M 20	A 18	M 1	M 18	M 29	J 12	J 26	J 10	J 24	A 7	A 21	S 4	S 18	O 3	O 17	O 31	N 15	N 28
Crustacea (cont.)																			
Amphipoda	–	0	–	–	0	2	0	0	0	0	–	–	0	13	0	–	–	–	–
Mysidacea	–	0	–	–	0	0	0	0	0	0	–	–	0	0	0	–	–	–	–
Brachyura	–	0	–	–	0	0	0	0	0	0	–	–	0	0	0	–	–	–	–
unidentified Crustacea	–	0	–	–	0	0	0	0	0	0	–	–	0	0	0	–	–	–	–
Echinodermata																			
<u>Strongylocentrotus droebachiensis</u>	–	0	–	–	0	4	0	6	10	5	–	–	14	13	47	–	–	–	–
Asteroidea	–	0	–	–	0	0	0	0	0	5	–	–	0	0	0	–	–	–	–
Ophiuroidea	–	0	–	–	0	6	14	4	15	2	–	–	5	0	4	–	–	–	–
Fish eggs																			
capelin eggs	–	0	–	–	0	0	0	0	0	0	–	–	0	0	0	–	–	–	–
<u>P. americanus</u> eggs	–	0	–	–	0	0	0	0	0	0	–	–	0	0	0	–	–	–	–
Fish remains																			
capelin	–	0	–	–	0	0	0	0	0	0	–	–	0	0	0	–	–	–	–
unidentified fish remains	–	0	–	–	0	0	0	0	0	0	–	–	0	0	0	–	–	–	–

APPENDIX J

St. Philips, Station B: the percentage volume of each food group per sample.

	Date																					
	F 7	M 19	A 18	M 6	M 16	M 30	J 11	J 27	J 11	J 25	A 8	A 22	S 6	S 19	O 4	O 18	N 1	N 16	N 29	D 13	J 24	F 8
unidentifiable organic matter	0	–	–	33	–	0	1	13	67	*	–	–	48	75	83	84	97	100	100	100	–	–
debris	0	–	–	0	–	0	0	2		*						0	0	0	0	0	–	–
algae	0	–	–	54	–	86	0	20	21	0	–	–	26	5	0	0	0	0	0	0	–	–
Coelenterata																						
Actiniaria	0	–	–	0	–	0	0	50	0	0	–	–	12	0	0	0	2	0	0	0	–	–
Mollusca																						
Polyplacophora	0	–	–	0	–	0	1	2	0	2	–	–	0	0	0	0	0	0	0	0	–	–
limpets	0	–	–	0	–	4	0	2	0	2	–	–	0	0	0	2	0	0	0	0	–	–
other Gastropoda	0	–	–	0	–	0	0	0	0	0	–	–	0	0	0	0	0	0	0	0	–	–
Pelecypoda	0	–	–	0	–	0	0	1	3	0	–	–	2	5	1	5	0	0	0	0	–	–
Nudibranchia	0	–	–	0	–	4	0	0	0	0	–	–	0	0	0	0	0	0	0	0	–	–
Annelida																						
sand tube Polychaeta	0	–	–	0	–	0	0	0	9	0	–	–	0	0	0	2	0	0	0	0	–	–
other Polychaeta	0	–	–	0	–	0	2	2	0	2	–	–	5	0	1	0	0	0	0	0	–	–
Oligochaeta	0	–	–	0	–	0	0	1	0	0	–	–	2	0	1	0	0	0	0	0	–	–
Crustacea																						
Cumacea	0	–	–	0	–	0	0	0	0	0	–	–	0	0	0	0	0	0	0	0	–	–

	Date																					
	F 7	M 19	A 18	M 6	M 16	M 30	J 11	J 27	J 11	J 25	A 8	A 22	S 6	S 19	O 4	O 18	N 1	N 16	N 29	D 13	J 24	F 8
Crustacea (cont.)																						
Isopoda	0	–	–	0	–	0	0	0	0	0	–	–	0	0	0	0	0	0	0	0	–	–
Amphipoda	0	–	–	8	–	0	1	1	0	0	–	–	1	2	7	0	0	0	0	0	–	–
Mysidacea	0	–	–	0	–	0	0	0	0	0	–	–	0	1	0	0	0	0	0	0	–	–
Brachyura	0	–	–	0	–	0	0	0	0	0	–	–	0	0	4	0	1	0	0	0	–	–
unidentified Crustacea	0	–	–	4	–	0	0	0	0	0	–	–	0	0	0	0	0	0	0	0	–	–
Echinodermata																						
S. droebachiensis	0	–	–	0	–	1	0	5	0	2	–	–	4	9	0	7	0	0	0	0	–	–
Asteroidea	0	–	–	0	–	0	0	1	0	0	–	–	0	3	0	0	0	0	0	0	–	–
Ophiuroidea	0	–	–	0	–	3	3	1	0	0	–	–	0	0	0	0	0	0	0	0	–	–
Fish eggs																						
capelin eggs	0	–	–	0	–	0	0	0	0	*	–	–	0	0	0	0	0	0	0	0	–	–
P. americanus eggs	0	–	–	0	–	0	0	0	0	0	–	–	0	0	0	0	0	0	0	0	–	–
Fish remains																						
capelin	0	–	–	0	–	0	0	0	0	0	–	–	0	0	0	0	0	0	0	0	–	–
unidentified fish remains	0	–	–	0	–	0	91	0	0	0	–	–	0	0	0	0	0	0	0	0	–	–

*July 25 : 91% = unidentified organic matter, debris, and capelin eggs (visual estimate of eggs: approximately 40%).

APPENDIX K

St. Philips, Station C: the percentage volume of each food group per sample.

	Date													
	J 11	J 25	A 8	A 22	S 6	S 19	O 4	O 18	N 1	N 16	N 29	D 14	J 25	F 8
unidentifiable organic matter	61	*	–	–	94	99	100	98	100	100	100	100	–	0
debris	1	*	–	–	0	0	0	0	0	0	0	0	–	0
algae	1	1	–	–	0	0	0	0	0	0	0	0	–	0
Coelenterata														
Actiniaria	0	1	–	–	0	0	0	0	0	0	0	0	–	0
Mollusca														
Polyplacophora	2	0	–	–	0	0	0	0	0	0	0	0	–	0
limpets	0	0	–	–	0	0	0	0	0	0	0	0	–	0
other Gastropoda	4	0	–	–	0	1	0	0	0	0	0	0	–	0
Pelecypoda	0	0	–	–	0	0	0	0	0	0	0	0	–	0
Annelida														
sand tube Polychaeta	1	0	–	–	0	0	0	0	0	0	0	0	–	0
other Polychaeta		0	–	–	2	0	0	0	0	0	0	0	–	0
Oligochaeta	0	0	–	–	0	0	0	0	0	0	0	0	–	0
Crustacea														
Cumacea	0	0	–	–	0	0	0	0	0	0	0	0	–	0
Isopoda	0	0	–	–	0	0	0	0	0	0	0	0	–	0

	Date													
	J 11	J 25	A 8	A 22	S 6	S 19	O 4	O 18	N 1	N 16	N 29	D 14	J 25	F 8
Crustacea (cont.)														
Amphipoda	1	0	-	-	2	0	0	0	0	0	0	0	-	0
Mysidacea	0	0	-	-	0	0	0	0	0	0	0	0	-	0
Brachyura	0	0	-	-	0	0	0	0	0	0	0	0	-	0
unidentified Crustacea	0	0	-	-	0	0	0	0	0	0	0	0	-	0
Echinodermata														
S. droebachiensis	26	0	-	-	2	0	0	0	0	0	0	0	-	0
Asteroidea	1	0	-	-	0	0	0	0	0	0	0	0	-	0
Ophiuroidea	0	0	-	-	0	0	0	0	0	0	0	0	-	0
Fish eggs														
capelin eggs	0	*	-	-	0	0	0	0	0	0	0	0	-	0
P. americanus eggs	0	0	-	-	0	0	0	0	0	0	0	0	-	0
Fish remains														
capelin	0	0	-	-	0	0	0	0	0	0	0	0	-	0
unidentified fish remains	0	0	-	-	0	0	0	0	0	0	0	0	-	0

*July 25: 98% = unidentified organic matter, debris, and capelin eggs (visual estimate of eggs = approx. 90%).

APPENDIX L

North Arm: dates of counts in each station, the number of counts made on each date, and the mean number of flounders per 300 square meter count on each date. Variation among counts on each date is given as two standard errors of the mean. Counts made with the portable quadrat were doubled to give the mean number of fish per 300 square meters. Counts in Station B after April 11 were transformed from fish per 420 square meters. The lines show the dates after which counts were made using permanent transects. Station D values give the number of flounders observed in 30 minutes.

Station A				Station B				Station D	
Date	No. of Counts	Mean No. Fish per 300 m^2 Count	$2s_{\bar{x}}$	Date	No. of Counts	Mean No. Fish per 300 m^2 Count	$2s_{\bar{x}}$	Date	No. Fish Observed in 30 Minutes
Feb. 2	1	32.0							
Feb. 14	1	24.0							
Feb. 22	1	36.0		Feb. 23	1	134.0			
Mar. 27	2	4.0	0	Mar. 26	2	1.0	1.6		
Apr. 10	2	15.0	4.8	Apr. 11	2	0	0	Apr. 13	0
May 10	1	10.0		May 11	2	8.5	4.0		
May 24	2	7.5	7.4	May 23	2	8.5	2.4		
June 5	2	35.0	12.0	June 6	2	6.0	0		
June 19	2	36.0	23.6	June 20	2	2.0	1.6	June 22	12
July 3	2	9.5	2.4	July 3	2	3.5	0.8		
July 18	2	7.0	6.6	July 18	2	3.0	3.2		
July 31	2	7.5	0.8	Aug. 1	2	5.5	7.4		
Aug. 14	2	20.5	0.8	Aug. 15	2	6.0	0	Aug. 17	18.3
Aug. 28	2	66.5	13.8	Aug. 29	2	19.5	2.4		
Sept. 11	2	62.5	20.4	Sept. 12	2	12.0	1.6		
Sept. 25	2	24.0	8.2	Sept. 26	2	16.5	5.8		
Oct. 10	2	4.5	2.4	Oct. 11	2	6.0	0		
Oct. 24	2	31.5	5.8	Oct. 25	2	15.5	4.0		

Station A				Station B				Station D	
Date	No. of Counts	Mean No. Fish per 300 m^2 Count	$2s_{\bar{x}}$	Date	No. of Counts	Mean No. Fish per 300 m^2 Count	$2s_{\bar{x}}$	Date	No. Fish Observed in 30 Minutes
Nov. 7	2	33.0	19.6	Nov. 8	2	36.5	9.0		
Nov. 21	2	8.5	0.8	Nov. 22	2	33.0	0		
Dec. 5	2	15.0	1.6	Dec. 6	2	6.5	0.8		
Dec. 17	2	2.5	0.8	Dec. 18	2	10.5	5.8		
Jan. 19	2	1.5	0.8	-	-	-			
Jan. 30	2	1.5	2.4	Feb. 1	-	7.0	1.6		
Mar. 1	2	0	0	Mar. 2	2	2.5	0.8		

APPENDIX M

St. Philips: dates of counts in each station, the number of counts made on each date, and the mean number of flounders per 300 square meter count on each date. Variation among counts on each date is given as two standard errors of the mean. Counts made with the portable quadrat were doubled to give the mean number of fish per 300 square meters. The lines show the dates after which counts were made using permanent transects. Station D values give the number of flounders observed in 30 minutes.

Station A				Station B				Station C				Station D	
Date	No. of Counts	Mean No. Fish Per 300 m^2 Count	$2s_{\bar{x}}$	Date	No. of Counts	Mean No. Fish Per 300 m^2 Count	$2s_{\bar{x}}$	Date	No. of Counts	Mean No. Fish Per 300 m^2 Count	$2s_{\bar{x}}$	Date	No. Fish Observed in 30 Minutes
Feb. 7	1	0		Feb. 7	1	2.0							
Mar. 20	2	1.0	1.6	Mar. 19	2	0	0					Mar. 21	3
Apr. 18	2	0	0	Apr. 18	2	0	0						
May 1	3	0	0	May 6	2	1.5	0.8						
May 18	2	1.0	1.6	May 16	2	7.0	3.2						
May 29	2	3.0	1.6	May 30	2	0	0					June 1	0
June 12	2	2.0	1.6	June 11	2	0.5	0.8						
June 26	2	0.5	0.8	June 27	2	5.5	9.0						
July 10	2	1.0	1.6	July 11	2	11.5	5.8	July 11	2	3.5	2.4		
July 24	2	0	0	July 25	2	1.0	1.6	July 25	2	1.0	1.6		
Aug. 7	2	0	0	Aug. 8	2	0	0	Aug. 8	2	0	0		
Aug. 21	2	0	0	Aug. 22	2	0.5	0.8	Aug. 22	1	0		Aug. 24	3
Sept. 4	2	0.5	0.8	Sept. 6	2	0.5	0.8	Sept. 6	2	1.5	0.8	Sept. 10	24
Sept. 18	2	0.5	0.8	Sept. 19	2	8.0	0	Sept. 19	2	12.5	2.4		
Oct. 3	2	1.5	0.8	Oct. 4	2	8.5	0.8	Oct. 4	2	10.0	4.8		
–	–	–		Oct. 18	2	4.0	0	Oct. 18	2	26.0	6.6		

Station A				Station B				Station C				Station D	
Date	No. of Counts	Mean No. Fish Per 300 m^2 Count	$2s_{\bar{x}}$	Date	No. of Counts	Mean No. Fish Per 300 m^2 Count	$2s_{\bar{x}}$	Date	No. of Counts	Mean No. Fish Per 300 m^2 Count	$2s_{\bar{x}}$	Date	No. Fish Observed in 30 Minutes
Oct. 31	2	0	0	Nov. 1	2	9.0	3.2	Nov. 1	2	9.5	0.8		
Nov. 15	2	0	0	Nov. 16	2	28.5	4.0	Nov. 16	2	14.0	0		
				Nov. 29	2	5.0	4.8	Nov. 29	2	4.0	0	Nov. 30	0
				Dec. 13	2	19.0	6.6	Dec. 14	2	12.5	4.0		
				Jan. 24	2	0	0	Jan. 25	2	0	0		
				Feb. [illegible]	2	0	0	Feb. 8	2	0	0		